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# Social network fragmentation in a team based organisation

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# Abstract

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**Abstract**

There is an enormous body of knowledge about social networks in organisations and about how the structure of those networks affect individual, team and organisation performance. Research has shown that network structure has its role for instance in collaboration, sharing of new ideas and getting advice. Especially important aspects are considered to be for instance weak ties and integration inside teams compared to connectivity over the whole network.

The general consensus in social network research encourages towards ensuring integration over large networks while still maintaining density of local communities. These aspects have been measured in multitude of organisations from companies to neighbourhood communities. However, most of the efforts have gathered around companies with traditional organisational structures, e.g., subunits and hierarchies. The purpose of this study is to shed light to the social network of a company with more unusual, team based, way of organising itself: the organisation has no hierarchy and its work is done mostly in highly isolated and independent teams.

A negative aspect in lack of integration over whole network is fragmentation. In this study it is shown to be present in the studied organisation and generating it potential hindrances. However, the organisation is also shown to have some integration over the whole network keeping communities together. Furthermore, the organisation is likely to benefit from its internally highly integrated teams. The results also indicate that social network analysis is a tool that can be successfully used to analyse team based organisations. Finally, work time reporting data used in the study is shown to be a practical data source for analysing social networks.

**Keywords** social network analysis, team based organisation, independent teams, non-hierarchical organisation, fragmentation, work time reporting

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Organisaatioiden sosiaalisista verkostoista on valtavasti tutkimustietoa oli kyse sitten verkostojen vaikutuksesta yksilön, tiimin tai koko organisaation suorituskykyyn. On esimerkiksi havaittu, että sosiaaliset verkostoilla on tärkeä rooli yhteistyön tekemisessä, uusien ideoiden levittämisessä ja avun saamisessa. Erityisen tärkeitä aiheita ovat muun muassa heikot siteet ja tiimien sisäinen tiiviys verrattuna ihmisten välisiin yhteyksiin koko organisaation mittakaavassa.

Yleisesti pidetään tärkeänä säilyttää laajemman orgnisaation läpi menevät siteet samassa, kun tiimien sisäinen tiheys kasvaa. Näitä verkostojen ominaisuuksia on mitattu monenlaisissa organisaatioissa yrityksistä naapurustoyhteisöihin. Siitä huolimatta, suurin osa tutkimuksista on yrityksistä, joissa on paljon perinteisiä organisaatioiden rakenteita kuten aliyksiköitä ja hierarkiaa. Tämä tutkimus keskittyykin tarkastelemaan yritystä, jolla on epätavallisempi tapa organisoitua: tutkitulla organisaatiolla ei ole hierarkiaa ja työ tehdään pääosin erittäin eriytyneissä ja itseohjautuvissa tiimeissä.

Pirstaloituminen on ongelma, joka syntyy, kun sosiaalisessa verkostossa ei ole riittävästi koko verkoston yli kulkevia siteitä. Tutkitussa organisaatiossa on havaittavissa pirstaloitumista, mistä voi olla haittaa yrityksen toiminnalle. Tästä huolimatta verkostossa on kuitenkin siteitä, jotka pitävät sen yhteisöjä kiinni toisissaan. Lisäksi yritykselle on todennäköisesti hyötyä sen tiimien tiiviistä rakenteesta. Tutkimuksen perusteella voidaan todeta, että sosiaalisten verkostojen analyysistä on hyötyä tiimeistä rakentuvia organisaatioita tutkittaessa. Tämän ohelle myös tutkimuksessa käytetyt työajan seurannan kirjaukset osoittautuivat hyväksi tietolähteeksi sosiaalisen verkoston analyysiin.

**Avainsanat** sosiaalisten verkostojen analyysi, tiimeistä rakentuva organisaatio, itsenäiset tiimit, hierarkiaton organisaatio, pirstaloituminen, työajan raportointi

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# 1. Introduction

Organisations and individuals can be studied from many perspectives – social network analysis having the ability to combine both of these subjects under one magnifying glass. The objective of this study is to use social network analysis for understanding the features of one organisation and, at the same time, broaden the knowledge we have about social networks in such organisations.

While social networks in organisations are related to both official and unofficial structures, there are organisations where the official structures are minimal – sometimes referred to as flat hierarchy organisations. Since arguably most organisations still have traditional hierarchies, these flat hierarchy organisations haven't received as much attention when it comes to the research of social networks. One object in this study is to contribute to bridging this gap in our understanding.

The organisation under research is a knowledge intensive consultancy company serving its customers in needs often related (but not restricted) to digital services. The company is a hybrid partner for its customers employing individuals with a tremendous range of competence from deep technology understanding to visual, content and business design.

The organisation structure of the company can be considered out of the ordinary since there is complete lack of a fixed formal hierarchy. In other words, no employee in the company has a manager appointed to her nor does any employee have formal power over other members of the organisation. This applies especially to those employees that work in consulting projects.

Most of the consulting work in the organisation is done in teams. Those teams are highly independent and are often located in the premises of the customer for whom the work is done. In this context independence of those teams stands for lack of managerial control from the external organisation and lack of need for the team to report to any single individual in the organisation outside the team. Furthermore, the teams strive towards independence from the outside organisation in such a way that they can pursue and reach their goals with minimal dependence on people who are not members of the team itself. In other terms, as far as possible, the teams should be able to reach their goals by themselves.

As work is done mostly in customer premises the company favours situations where one person is a member in one team and one team only, and all the members in one team work together (physically and socially) as much as possible. The length of the projects and assignments the teams work with vary from a couple of weeks to multiple years. The teams are formed separately for each project and mostly the same team does not continue together after their project or assignment has finished. In shorter projects, the teams often have similar formations throughout the endeavour but in projects lasting multiple years it is not uncommon for consultants to leave teams and join new ones.

For billing purposes the company has work time reporting that is critical and mandatory for all employees, especially those working in customer projects. While the reporting data is important for the company itself also the consultants themselves are particularly motivated to report their billable hours correctly. In this study, that data is used to analyse the social network of the organisation.

## 1.1 Motivations

This section highlights the motivations behind this study and pinpoints the literature that supports investigating the subject described above. The perspective to the importance of this study is divided into two: the both use of social network analysis and the subject as a non-hierarchical organisation with independent teams are discussed.

Meta-analysis of Balkundi and Harrison (2006) is certainly a good indication of how great deal of research has been done about the correlations and causalities between teams and social network structure. On one hand, adding to that research most likely has only a minor effect on our understanding about the subject. On the other hand, it is then increasingly useful to find ways to utilise that body of knowledge in a larger variety of organisations, and potentially to find organisations where the knowledge isn't completely applicable. That opportunity of using the knowledge in new contexts and potentially finding exceptions for it makes organisation observed in this study interesting subject since its structure and way of organising work can be regarded as rather unconventional.

Based on the discrepancy between their expectations and observations Lincoln and Miller (1979) made the conclusion that investigators have to go deep into a network to understand it. Their suggestion is that for instance surveys and questionnaires are not enough but case studies are required. Especially those studies should take into consideration the time dimension and fluctuation in organisations. This study aspires to take into account this suggestion by investigating a single organisation closely, in several points in time.

*Social network perspective*

The fundamental premise of this study is that the structure of the social networks of an organisation has an effect on the performance of that organisation. At an elementary level, the purpose of using social network perspective is that it is required to fully understand individual behaviour. In other words, to understand the behaviour of individuals in organisations, it is both useful (Rowley, 1997) and necessary (Granovetter, 1985) to consider the relational context, i.e., the social network.

It can be natural to expect that in formal organisations, the organisation chart determines the patterns that communication between individuals take. This is, however, too narrow a perspective. The informal networks in organisations works as mediators for work related interaction, as well as formal ones (Lincoln & Miller, 1979). This is why it is fruitful to examine the social network structure when trying

to understand performance of an organisation. Furthermore, one question this study is also interested in is what are is an organisation structure like when there is no official organisation or its definition is intentionally unclear.

As a more concrete support for a social network perspective, it is known that the structure of teams' and organisation's social networks has an effect on team performance and it is recommended to incorporate social network perspective when studying teams (Balkundi & Harrison, 2006). The effect on teams is especially important since this study is specifically interested in team based organisations.

One encouraging example about the usefulness of social network perspective in team research comes from Reagans, Zuckerman, and McEvily (2004). Their initial idea is that research of team performance through team diversity is unlikely to ever deliver consistent results – instead, their opinion is that direct measurements of team internal and external social networks should be used. To motivate this study more, Reagans et al. support the opinion that social network analysis should be used even if it is more difficult than using other measures: they found significant positive returns arising from optimising social networks of teams. Furthermore, Reagans et al. use manual methods for instance for collecting the date about organisation member social networks. This is to say, by automating the process could increase the returns even more in long perspective.

When considering organisation structures, a simple description is often easy to find in form of organisation chart. However, it doesn't describe the informal structures of the organisation. This is why the investigation of social networks is required. To elaborate the magnitude of the importance of understanding informal organisational structures, an example can be borrowed from Lincoln and Miller (1979): they observed that there was both racial and gender inequality in an organisation that was not explainable using the formal structure of the organisation.

Dependent on the context, a formal organisation chart may not even be available. In these situations understanding the functioning of the organisation through social network analysis is the best option, for instance, for pin pointing the most important and central figures in the organisation (Tyler, Wilkinson, & Huberman, 2003).

Even if work was done in teams, the social networks of individual members are

still important. Individuals don't leave their ties behind but are simultaneously part of the team, with ties within the team, and part of a larger social network (Rosenthal, 1997). This specific aspect can be considered well in social network analysis since the organisation is observed simultaneously from individual and organisational point of view.

To better understand the importance of social network perspective, it is useful to consider what the causal mechanism between social network structure and organisation and team performance is. There is considerable support for the view that knowledge transfer is the mediator (e.g. Reagans & McEvily, 2003; Ingram & Roberts, 2000; Reagans & Zuckerman, 2001; Tsai, 2001): social network structure can increase or decrease organisation's ability to transfer knowledge internally which then improves or worsens the performance of that organisation. With that relationship, it can be expected that the magnitude of the effect of social network structure depends on the importance of knowledge transfer. In other words, if knowledge transfer is especially important for an organisation, it can significantly benefit from having a suitable social network structure.

*Non-hierarchical organisation with independent teams*

Reagans et al. (2004) have done an important publication about team performance using a social network approach at the core of their research. However, the concrete process they look at is how a manager is able to form a team. Their questions and conclusions are highly based on the idea that there is a manager that can control the team structure based on available information. The question that is left at least partially unanswered is what the team structure will be like when there is no managerial control but the team is built in a more organic way: in an organisation without a hierarchy individuals themselves have a great deal of power and they direct the team structure toward a form that they seem appropriate.

In their study, Tyler et al. (2003) suggest that (automated) social network analysis can be used to understand organisations from which there is no organisational chart available or no such chart exists. A non-hierarchical organisation is an excellent subject to study when trying to validate that suggestion. Furthermore, if the lack

of hierarchy and independence of teams is not taken as granted it is interesting to see whether social network analysis is able to confirm those believes about an organisation. In other words, social network analysis may reveal hierarchical features or lack of autonomy in an organisation even if those aspects are not expected to be present.

## 1.2 Research questions

This section describes the objectives of this study in the form of research questions. This study aims at answering those questions using previous research, empirical evidence, or both. The questions are listed below and further explanation for each question follows after the list.

- Does social network fragmentation cause hindrances in performance for team based organisations?

- From social network perspective, are highly independent teams a beneficial organisation structure?

- Can social network analysis reveal issues and strength in a highly team based organisation?

- Can work time reporting data be used effectively in social network analysis?

*Does social network fragmentation cause hindrances in performance for team based organisations?*
Some organisations are formed mainly around teams. In such organisations, teams are the predominant construction block where most of the members of the organisation belong to. These teams can be very independent. That is, they make decisions themselves and answer themselves for the rest of the organisation and the customer they serve. Furthermore, these organisations don't necessarily need a hierarchy

since the teams don't require external or internal management. However, it can be expected that these teams may concentrate on internal integration at the expense of their external connectivity. Thus, based on the work of, e.g., Granovetter (1973) this may separate the teams from each other and fragment the organisation causing hindrances to its performance.

This question is answered in two parts: Are there hindrances that arise from high internal integration combined with low external connectivity? Does this pattern occur in team based organisation? For the first part, previous research is consulted to form a picture about the potential issues and the forms in which those issues would manifest themselves. The second part is answered using empirical findings from the studied organisation. These findings are compared with the theory to identify if the problematic features are present in the organisation.

*From social network perspective, are highly independent teams a beneficial organisation structure?*

The purpose of this question is to continue where the previous one left. While the first question examines if the independent teams cause hindrances this question considers whether there are potential performance gains to be made using independent teams. This dichotomy between the issues and benefits of internally integrated and externally disconnected teams is clearly visible in previous literature and this study tries to build on that basis. For instance, both Reagans and Zuckerman (2001) and Reagans et al. (2004) deal with this question and have found the premise to be true. The importance of this question paired with the first one is in their ability to enable a more holistic view on the subject of organisation structure. They highlight the significant matter that team based organisation structure is potentially both beneficial and harmful and thus the subject should not be approached with only one of these angles in mind. Furthermore, it is possible that organisations don't have to experience the hindrances in the same extent as the benefits which would lead to a positive net outcome. Of course, the opposite is also true.

To answer the question at hand, similar methods are used as with the first one: both theory from previous research is considered and empirical findings are gathered. Partially, the theoretical material provides a wider and more extensive perspective

and that is why it is of great significance. However, the empirical part should be able to create understanding about organisation specific matters and especially should help the organisation at hand. One method that is also employed to answer this question is the comparison of the social networks of typical organisations and of the organisation observed in this study. This enables pinpointing the abnormalities that team based organisations have in their social networks; or the lack of such.

A key aspect that is explored in both these questions is the role of tie strength: how ties with different strengths have different roles in the social network of an organisation and, on the other hand, how structures and mechanisms of an organisation cause tie strength to be distributed around the network of that organisation. Especially, these research questions consider how distinct the situation becomes if perspective is changed from one tie strength to another. The significance of tie strength is taken into consideration in both theoretical and empirical parts.

*Can social network analysis reveal issues and strength in a highly team based organisation?*

This research question combines two objectives. First of all, from answering the first two questions it should become evident whether social network analysis used as a tool in this study is able to highlight issues or strengths in an organisation. From the perspective of theory, there should be significant findings that indicate a causal relationship between social network structure and organisation or team performance. However, that is not enough. Also such empirical evidence is required which indicates that the phenomena discussed in previous literature can be highlighted in an actual social network given sufficient data.

The second objective included in the question is to find out whether using social network analysis is both practical and reliable. The existing body of knowledge about social networks and, for instance, team performance indicates that revealing insights about an organisation is possible using social network analysis. However, that research does not necessarily indicate what the net benefits of that analysis are and whether those benefits apply universally. Most importantly, this study strives towards showing that a certain organisation can be understood better using the data that is available.

Another way of forming this question would be to ask whether organisations could gather useful insight about themselves using social network analysis – or whether they should be using social network analysis to help them perform better in the future. As explained above, the purpose of this study is not to directly answer this question but the answer follows from other results. However, this question is of significant importance since it helps organisations in future decide whether they should use social network analysis as a tool in their internal development.

*Can work time reporting data be used effectively in social network analysis?*
The empirical part of this study is based work time reporting data. The data is easily available from the studied organisation and it is expected to provide enough information to form a social network. However, the data itself does not explicitly contain the social network and neither does it directly describe communication or contacts between members of the organisation. Thus, using work time reporting as a data source for social network analysis one has to infer the dyads in the network based the information that is available. This naturally leads to a situation where not all dyads can be inferred. Furthermore, work time reporting contains information that indicates more social network ties that there is in reality. The purpose of this study is to strive for empirical evidence about if work time reporting can be used to infer a social network of an organisation and if the resulting network can be effectively used in analysing the organisation.

This question is studied mainly with empirical methods. The primary form of research is included in the analysis of the network for the purposes of the previous questions: if the other questions can be successfully answered using the work time reporting data, one indication is found to support the usefulness of this set. Special interest is in what forms of analysis can not be conducted reliably using the work time reporting data and, on the other hand, is there a form of analysis that could not be done using other methods used in previous research, including email data (Guimera, Danon, Diaz-Guilera, Giralt, & Arenas, 2003) and surveys (e.g. Reagans et al., 2004). The second way of investigating the usefulness of work time reporting data with empirical methods is the analysis of the data itself and how the social network can be inferred from it.

# 2. Typical features of social networks

To be able to find abnormalities in the social network structure of an organisation consisting of independent teams, it is necessary to first describe social networks of organisations considered normal. In this study, two perspectives are used: what is typical for all social networks, and what are the typical features of social networks documented in organisations.

## 2.1 Network structures of social networks

The structure of a social network is formed by ties: dyadic connections between social parties (Balkundi & Harrison, 2006) also known as nodes (Nadel, 1957). Ties are the enablers for two individuals to convey resources, e.g., information (Balkundi & Harrison, 2006).

A typical feature of a social network is that from the perspective of an individual, there is always a central part of the network and a peripheral part: individuals spend most of their time communicating with only a few of their contacts and most of their network receives little attention (Miritello et al., 2013; Milardo, Johnson, & Huston, 1983). The ties that receives most of the attention are called strong ties and the ties left with small amount of attention are weak ties (Granovetter, 1973; Miritello et al., 2013). Separating ties with different strengths is useful since it helps in understanding dynamics in human behaviour and in explaining certain structures of social networks (Miritello et al., 2013).

A feature that is related to the separation between close contacts and distant contacts is communities and community structure. In many networks, including social networks, there is a tendency for nodes to form groups or communities (Guimera et al., 2003) with large amount of connections inside the group and few connections between the groups (Newman & Girvan, 2003; Girvan & Newman, 2002). Furthermore, Guimera et al. notices that not only are there communities in an organisation but they tend to form larger communities, "groups of groups".

In some contexts, social networks are described as small world networks. The small world name stems from the network feature where the nodes of the network have relatively short distances to every other node in the network (Watts, 2004). More precisely, when the size of the network grows the average shortest path from one node to any other node doesn't increase in the same proportion – the average path length growth is smaller. Another characterising feature of a small world network is that it consists of clusters where the nodes of the cluster have redundant ties, i.e., multiple paths through which to contact each other. (White & Houseman, 2002) It is necessary to be mentioned that social networks are not the only small world networks (Watts & Strogatz, 1998) and thus this feature doesn't completely separate social networks from other networks. However, from the perspective of this study, being a small world network is highly significant.

Since this study is interested in how the structure of organisation's social network affects that organisation, "small-worldness" of social networks constitutes a major factor. This is since in small world networks, only a minor change in the connections of the network can have a dramatic effect on the measured outcome (Watts & Strogatz, 1998). More precisely, replacing a local tie with a more global tie creates a surprisingly large change in the functioning of the network.

One feature of networks is navigability or searchability: the ease with which one can find required node or information in network (White & Houseman, 2002). To separate path length from navigability it has to be considered if individual nodes are able to find the shortest path: in networks with poor navigability distances may be short but information moves through unnecessarily long paths. The classic study by Travers and Milgram (1969) investigated the navigability of social networks and

found out that the navigation is considerable effective.

Compared to other networks, social networks tend to have large variation in centrality (Balkundi & Harrison, 2006). Centrality stands for individual's position related to others. To elaborate, the most central individual in a network has the most direct (or indirect) ties to other network members (Provan, Veazie, Staten, & Teufel-Shone, 2005). Another term describing the amount of ties an individual has is the degree of a node (Miritello et al., 2013). It is known that centrality has both positive and negative effects on the individual and potentially for the members of the network she is connected to (e.g. Adler & Kwon, 2002; Mayhew & Levinger, 1976).

Using the term 'variation' about differences in the degrees of nodes is misleading, though. By using standard variation and Normal distribution the differences can't be fully explained since the variation is not large enough. The key feature of social networks is the distribution of the degree of nodes: the degree follows skewed long tailed distribution (Miritello et al., 2013). In other terms, while most nodes have their degree near but below average there are nodes with incredibly high amounts of connections. Because of this feature, among some other networks, social networks are called scale-free networks (Watts, 2004). This stems from the distribution of node degree following a power law where for each degree there is always a reasonable probability of node existing with an even higher degree.

When considering social network features, it should be noted that they may be highly dependent on the perspective from which they are looked at: in one measurement an individual may be central in a network while another way of measuring puts the same individual in a less central position. This stems from there being several types of ties in social network. (Provan et al., 2005)

One driving force in social network structure is homophily (e.g. Rogers & Bhowmik, 1970; Lazarsfeld & Merton, 1954). Homophily stands for how similar connected individuals are (Lazarsfeld & Merton, 1954). In social networks, individuals tend to have ties more to people like them than to people unlike them.

## 2.2 Organisation social network structure

At an abstract level, no effort is required to understand how organisation are social networks. Independent of the structure of the organisation, there are ties between members of the organisation. Furthermore, the ties have features like strength and the members have differences in the distribution and amount of their ties. Then, the question worth asking is, what the social network of a given organisation is like.

It has been suggested that in formal organisations, there are two kinds of ties: instrumental and primary ties. Instrumental ties are related to individual's role in the formal organisation, when primary ties are more social and related to the informal structure of an organisation. (Lincoln & Miller, 1979) In other terms, the network of instrumental ties and the positions of its nodes in the network are the structure that organisational charts describe (Friedell, 1967).

Even if there are social networks in organisations like there are in more informal environments, there are differences between these networks. Most surprisingly, there are differences in informal primary networks, dependent on if the environment is formal or informal (Lincoln & Miller, 1979). Lincoln and Miller expect that this would be due to the fact that in formal organisations, individuals cannot choose who they are involved with.

As described earlier, even in formal organisations informal social networks have great significance. They are used for work related interaction (Lincoln & Miller, 1979) like task advice, decision-making and learning (Provan et al., 2005; Tyler et al., 2003). Informal networks are utilised especially in unexpected situations while formal networks are designed for routine work (Guimera et al., 2003). Furthermore, one feature of both formal and informal social networks in organisations is that individuals with high status tend to have a central position in the network (Lincoln & Miller, 1979; Tyler et al., 2003).

Especially from research perspective, social networks in formal organisation and in informal settings have a clear difference. Lincoln and Miller (1979) bring up that networks in formal organisations are almost consistently uniform, i.e., all members of the organisation have a direct or an indirect link to every other member. For other

social networks, it is possible that there are unconnected fragments.

Academics generally see that social networks are valuable for organisations. To represent that value, the term social capital is used. It is in some sense similar to financial and physical capital (i.e., money and tools available) and to human capital (i.e., employees and their skills) but it describes the social features of an organisation that consist of, among other things, social networks and social trust (Putnam, 1995). These organisational features improve coordination and collaboration and thus produce mutual benefit (Putnam, 1995) or in other words, improve the ability of individuals to work together for the common good (Hasle, Kristensen, Møller, & Olesen, 2007).

In addition to benefits for an organisation as a whole, social network affects the status and abilities of individuals in the organisation. One important network structure related to a beneficial position in a social network is a structural hole (Provan et al., 2005). Burt (2009) originally described that a structural hole creates a nonredundant connection between two contacts. When an individual is able to bridge the gap over a structural hole, she is able to reach new (and thus better) information compared to other members of her group (Burt, 2009).

An interesting question is, whether there are general guidelines that can be used to understand social network formation and structure in organisations. One such guideline, as Lincoln and Miller (1979) describe it, can be rational design. It is an idea that network structures form so that they rationally optimise the performance of the organisation related to the network. Even if it may not have much predictive power, it can be used to explain some phenomena in social networks. For instance, Lincoln and Miller conclude that it may be the driving principle behind some forms of inequality observed in organisations.

As it is usual for social networks, organisational social networks have groups or communities (e.g. Newman & Girvan, 2003). Research has found out that there may not be any fixed community size in an organisation but there can be a large array of different sizes of communities. Furthermore, the size of those communities follows skewed power law distribution in such a manner that even large communities are relatively common. (Guimera et al., 2003; Gleiser & Danon, 2003) Guimera et al.

also suggest that these communities form self-similar structures where communities contain smaller communities structurally similar to the larger community. Their view is that this is due to the tendency of an organisation to create constantly structures of a certain kind because of a trade-offs between need for cooperation and physical constraints.

While the research about community or group structure suggest that there are a great variety of group sizes in social networks, it is also true that there are certain restrictions. When there is a pattern that affects the formation of the groups, it is possible that for instance particularly large or small groups are less likely than what the power law distribution would predict. Gleiser and Danon (2003) observed this when studying jazz community structures. They noticed that very small communities are less frequent than expected. Their conclusion is that this occurs since jazz musicians organise themselves in bands which are unlikely to be very small. Both Guimera et al. (2003) and Gleiser and Danon (2003) observed that there is also an upper limit for group size after which groups become less likely at a substantially higher pace.

While clearly social networks of organisations consist of groups it is not guaranteed that all individuals are purely members of one and only one group. Tyler et al. (2003) observed in their study that individuals may be positioned between two groups: they are not connected to either group as tightly as the other members of the group but still they can be regarded as members of either group.

# 3. Independent teams

In this study, the main interest is in organisation where the way of organising work is heavily based on independent teams. The purpose of this section is to investigate current research about the performance of such teams. It is necessary to take two perspectives: First perspective is the tight integration of independent teams and the strengths and weaknesses they bring. Second perspective is the separation of the teams from each other and how that is a potential source of problems in the organisation.

In the approach described above there is hardly anything novel: for instance Ancona and Caldwell (1992) mentions this dichotomy in a study about team performance and Reagans et al. (2004) further rigorously study the effects of these two network phenomena. However, there are multiple paths through which those network features can be achieved in an organisation and for instance Reagans et al. (2004) reach the conclusion that most likely controlling team demographic diversity is not an effective way for that. Instead, Reagans et al. suggest that concretely utilising information about organisation social networks is more effective.

To be able to apply social network perspective to groups and teams of people, we must be able to describe them with concepts used in social network analysis. A useful concept is clique: an array of nodes in a network that are all highly connected to each other (Scott, 2000; Krackhardt, 1999). The feature of groups that stems from the clique structure is that there is redundancy in ties. In other words, there are more ties than necessary through which you can find a connection to a person.

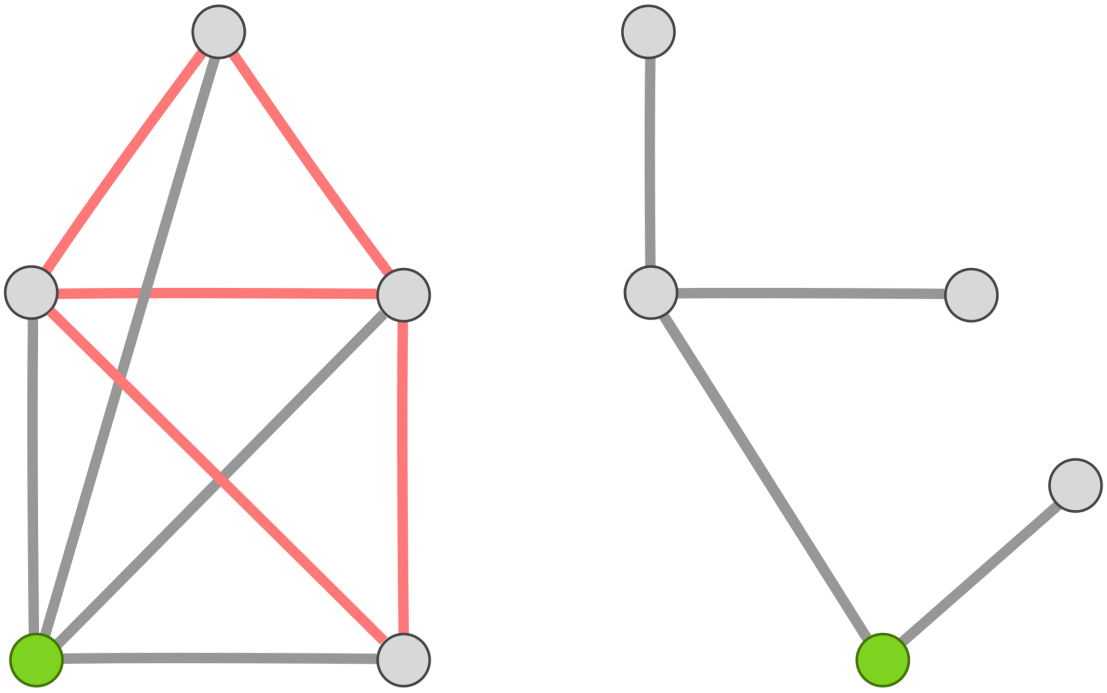


**Figure 3.1.** High constraint and high range networks illustrated. From the perspective of ego (green node) the red ties are redundant. The network on the left has high constraint since alters are all connected together and thus their ties don't increase the range of ego's network. Thus, while ego has four ties she only has four contacts. The network on the right has high range since alters' time is not spent communicating with other alters but with new individuals outside of ego's direct contacts. This leads to ego having access to four other individuals with only two ties.

One meter for identifying an array of nodes as a clique is density. Density is the proportion of existing ties from the ties that could exist (Balkundi & Harrison, 2006). In a clique, density is very high since most individuals are connected directly to each other.

Network constraint is a useful concept in separating different kinds of social network structures. Constraint as a measure describes how big proportion of individual's ties eventually lead to another individual in the network (Rosenthal, 1997). As Rosenthal describes: "A clique, where there is a high degree of overlap between contacts, is an illustration of a highly constrained network. A low constraint network,

on the other hand, has few redundant contacts and less interconnections between contacts." Figure 3.1 illustrates this difference. In the setting of independent teams, the network is a high constrain network: team members have a large amount of redundant ties to each other but only a few to the surrounding network. Concepts that are also used are network density and network range (Reagans et al., 2004). To describe the meaning of the concepts, a highly constrained and cliqued network has high network density and a low constrained network has high network range.

In most extreme case, very constrained social network can reach a point where all members in the network are not connected anymore. That is, there is no direct or indirect connection between some individuals. The term for this is fragmentation (Provan et al., 2005).

## 3.1 Intra-group connectivity

This study is specifically interested in teams with high network density. To further elaborate, such teams are highly cliqued and thus highly constrained. These kind of teams can be viewed from a variety of perspectives, and by using that wide perspective it is possible to find research that show multitude of benefits in this kind of team setting. However, there are also hindrances that are related to these very cliqued teams.

Simmelian tie is a useful concept that can be used for describing a relationship between two individuals in a clique. It is described by Krackhardt (1999) as a strong reciprocal tie between two individuals where both individuals also have a similar tie to a third person. This pattern is illustrated in Figure 3.2. The idea of this triad was originally introduced by Simmel (1950). To be strict, a clique must form only from Simmelian ties.

Even if Simmelian tie considers only a relationship between two (or three) individuals, it is benefits have significant consequences to cliques. Krackhardt (originally by Simmel, 1950) describes three major advantages that cliques of Simmelian ties have over any group with sparse connectivity:

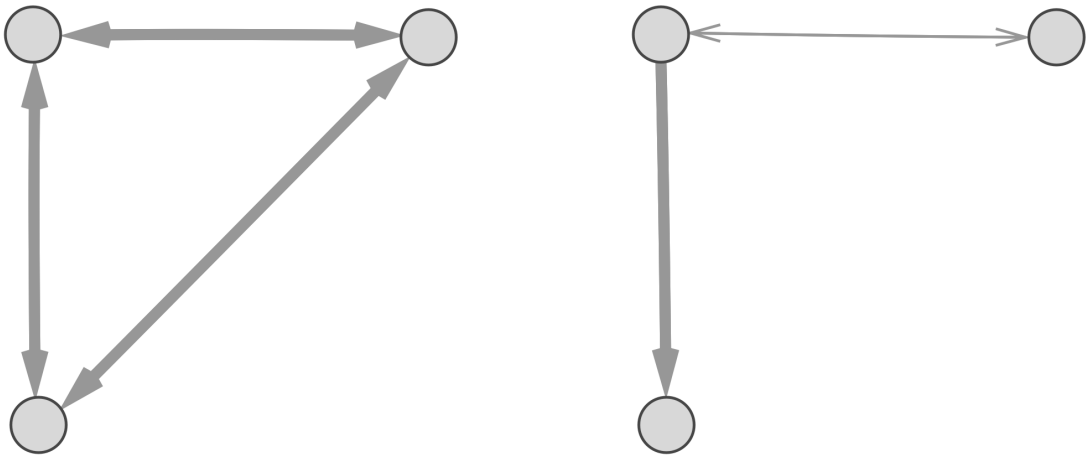


**Figure 3.2.** Illustration of three nodes with and without Simmelian ties. The triad on the left has three Simmelian ties: all the nodes have reciprocal ties to other individuals who are connected with a similar tie. On the right, the nodes are connected with ties that are not reciprocal or the other nodes the central node is connected to don't have a tie together.

- The interest of the group or clique is followed over the interest of individuals since the rest of the clique can always form and support opposing opinion than that of any individual's.

- Individuals have less bargaining power, for instance by threatening to leave the group, since the structure of the group is not dependent on any individual.

- Conflicts between individuals are less maleficent since other members of the clique ameliorate the conflict and can help to resolve it.

Because of the benefits described above, internally highly integrated teams are stronger than other setups for collaboration where the social networks of individuals are less dense. However, it can be expected that introducing transformation in cliques is more difficult since cliques should be good at maintaining their opinion and "avoiding" new ideas coming from a single member.

By using the social network perspective, a very principal feature of groups can be

identified: group members tightly connected to each other tend to share the same information, trust each other and have similar attitudes (Krackhardt, 1999).

Ancona and Caldwell (1992) have made on interesting observation about social integration in teams: diversity in teams leads to decreased social integration and thus impedes team performance; even if diversity could also have an indirect positive effect on the performance. For this study, the most significant finding from Ancona and Caldwell is that diversity and potentially poor social integration overrun the positive effects that are also present. Reagans et al. (2004) describe the same relationship as Ancona and Caldwell but more specifically from social network perspective. They explicitly state that the opposing features of teams are internal network density and outside network range. This study will further look at outside network range in the next section but so far it is useful to notice that when adjusting the team (demographic) diversity there is an opposite effect on network density and outside range: increasing diversity decreases internal network density but increases network range. Based on the effects described above, it has to be expected that highly integrated independent teams can be a recommendable option even if they bring some negative effects but also their integration should not be pursued by blindly decreasing diversity. At least if short term results are considered a central measure of success, having teams with similar members can be beneficial (Reagans & McEvily, 2003).

When considering the internal network density in a team, it is important to notice that the results are still contradicting with regard to whether network density inside groups is positively correlated with group performance, or not. For instance, Reagans et al. (2004) and Reagans and Zuckerman (2001) argue that the positive relationship exists but Sparrowe, Liden, Wayne, and Kraimer (2001) didn't find group density to have the aforementioned correlation when they investigated network providing advice for an individual. Research from Ancona and Caldwell (1992) provides encouraging support for the causality between team network density and team performance. The reason their research is especially important is that they use team diversity as an instrumental for team internal integration (i.e. internal network density). However, it is not definite by any means that lack of diversity would lead

to increased performance only through team network density.

## 3.2 Problems of separated groups

As Granovetter (1973) discusses in his article having closed groups causes issues when it comes to the adopting of, for instance, new products. In more precise terms, a closed group is a clique where individuals can be very well connected – inside the clique – but there are no (or very few) ties to the outside nodes of the network. Because of the lack of ties to other people there are no personal encounters through which information could travel. It has been shown that without personal ties, receiving information only from mass media, adoption is poor (Granovetter, 1973). This will eventually lead to hindered adoption in groups that may form an internally dense network but that lacks in ties to outside people.

In the subject of hindered transmission of information Granovetter only mentions information that affects ones willingness for taking a product or organisation seriously. However, since Granovetter's argument is based on lack of ties between people, the problem described applies to any information since no information can be transmitted over a structural hole. Thus, we can extend the issue to the hindered adoption of new ideas, new tools and new ways of working, for instance.

This is not a problem per se: it doesn't cause any direct issues for the group (or clique) itself. Since lack of information can be fundamentally impossible to observe, it may even be that inside the clique there is a complete ignorance of this issue. There is, however, a problem if we look from the perspective of the whole organisation. The problem is a poor utilisation of the potential of the organisation. If, in a hypothetical organisation, some part of the organisation has adopted a new idea that improves its performance, the clique separated from the organisation will not be able to receive information about the idea and thus won't adopt it. As Granovetter (1973) states the idea has to emerge independently in each clique. Simply put, this leads to increase in the total time of work that is done in some part of the organisation with worse performance than there would have been if the idea had been adopted.

However, while a group may not realise it is missing out on useful new tools, it is

probable that its lack of necessary skills, information and experience is noticeable inside the group itself. That hindrance may be alleviated by having good connectivity to individuals outside the team – especially when those individuals come from a diverse background (Reagans & Zuckerman, 2001). Thus, when in a search for help, a team may find the fragmentation of social network problematic since it makes it more difficult to find those outside-team individuals with the right background. The concept of constraint describes this issue well: in a highly cliqued network lacking weak ties, individuals have restricted access to useful information – i.e., they are constrained (Rosenthal, 1997).

In the subject of obtaining information, it is important to notice the usefulness of the information in addition to the access. In their article White and Houseman (2002) describe that weak ties, i.e., connections to people outside one's everyday contacts, are the most useful ties when looking for information. More precisely, weak ties provide the information that proves to be the most important. The value of the information is closely related to the adoption of new ideas described by Granovetter (1973): through strong ties individuals receive information that they already have and the useful new information is received through weak ties. When it comes to the value of ideas, similar pattern has been found: individuals with densely connected (high constraint) networks around them tend to have ideas that are perceived as low value while individuals with low constraint networks propose ideas that are valued more (Burt, 2004). As Burt explains, the value of the idea is not different, per se; but the difference is in who is evaluating the idea and how they credit it: "An idea mundane in one group can be a valuable insight in another. ... An idea is as valuable as an audience is willing to credit it with being."

While mainly theoretical research clearly suggests that group's lack of weak ties outside the group hinders access to resources such as help and new ideas (Granovetter, 1973), there is still a need for evidence about the association of lack of weak ties to actual team performance. Rosenthal (1997) has produced empirical results to support the association. However, Rosenthal has two restricting aspects in her conclusion: Firstly, she explicitly posits that the teams that benefit from weak ties have to require access to outside information. Secondly, her study is based on a

rather small sample size and the estimation of team performance is done using only one estimator.

When assessing the magnitude of issues brought by the fragmentation of the social network of an organisation, the findings from Ancona and Caldwell (1992) are useful. As described earlier they conclude that diverse teams perform worse than less diverse teams. One of their suggestions is that even if diversity increases connectivity to the organisation outside a group, the potential benefit from resources, e.g., support and new ideas, obtained from outside are too small compared to the decreased performance of the group itself. This brings up the question whether the benefits from for instance weak ties can be of small magnitude or can be easily reversed when the information can't be used effectively.

The benefit of connectedness outside one's closest network is also supported in the individual level: students have been found to perform better academically when they have a larger proportion of their ties outside of the group of their peers (Thomas, 2000). Thomas has also found out that there is more to connectedness than just performance. For instance, having inbound ties (i.e., individuals who mention one as a tie) is associated with social integration and willingness to be part of an institution.

While lack of ties across organisation is not desirable neither should organisations reach towards broad connectedness across their whole network. Provan and Sebastian (1998) clearly state: "Full-scale integration among the scores of firms that compose the complete network is neither needed nor desirable". However, Provan and Sebastian is referring to integration between firms working together, not individuals. That increases the absolute scale of the network making it more difficult to maintain wide integration. Provan and Sebastian (1998) further goes to explain that it is more preferable to have ties between key people of each clique instead of having loose integration across the whole network. The data behind the article promotes the view that overlap between cliques is a factor affecting performance positively in service work.

To get into more detail with the argument of Provan and Sebastian (1998), the pivotal factor determining the need for integration through the network is the requirements of the clients the network is trying to serve. To elaborate, the overlapping

cliques are useful when they improve the ability of the network to help clients in their complex and wide problems. Since the article by Provan and Sebastian considers firms that are typically specialised and not able to fulfil all the needs of a client, the notion about overlapping cliques may not apply to different contexts. Especially, the requirement for integration may decrease when the cliques of the organisation have more wide variety of skills inside the clique, thus requiring less help from other cliques outside the network. Reagans and Zuckerman (2001) also support this view: groups with only a narrow set of skills are more limited and thus more reliant on outside connections.

As Reagans and Zuckerman (2001) implicitly indicate, there is a balance between the diversity of group's member's skills and the level of connectivity to the outside network: the more a group has necessary skills and knowledge internally, the less it requires assistance from outside. Their finding is that in R&D teams a more important factor is the connectivity, i.e., lack of skill diversity in a group is acceptable and preferred over lack of ties to the surrounding network.

Long after Granovetter's notion about the importance of weak ties, research has formed another perspective that can be used to describe fragmented networks formed from cliques. It has been shown that individuals don't have to have weak ties to access a broad network of other individuals but one can reconnect old ties (Levin, Walter, & Murnighan, 2011). This does not invalidate the findings of Granovetter since the benefits of reconnecting ties are based on the same principles as he initially brought forward. However, in social network analysis a change in practises should be made so that fragmentation is not recognised purely as lack of weak ties but as lack of weak and reconnectable ties.

As mentioned earlier about social networks in general, the navigability of social networks can enable finding relatively short paths from one individual to another (Travers & Milgram, 1969). That is, however, highly dependent on the structure of the network and certain structures in social networks can cause significantly reduces navigability (White & Houseman, 2002). A large base of study (e.g. Granovetter, 1973; Travers & Milgram, 1969; Watts, 1999) supports the view that weak ties are essential in improving navigability in large networks (White & Houseman, 2002). In

other words, an organisation consisting of separated groups and lacking weak ties is predicted to suffer from poor navigability.

As ability to transfer knowledge is a key outcome of social network structure, network fragmentation can be understood as inability to convey knowledge across organisation. With such a perspective, we have to consider what other factors there are in network structure that inhibit such knowledge transfer. Interestingly, likelihood for transferring knowledge is not purely based on the path between two individuals but there are other determining structural aspects. Namely, the diversity of individuals own network increases one's ability to convey information to distant parts of an organisation (Reagans & McEvily, 2003). The reason is that individuals with diverse networks are more able to communicate with people around an organisation who are most likely somewhat different than she is when it comes to background knowledge. Thus, if the groups at hand consist of specialists that are in many sense rather similar to each other, the members of the groups may not be able to communicate with other teams over weak ties. On the other hand, for diverse groups the issues of network fragmentation are fewer.

What Reagans and McEvily (2003) also noticed is that difficult communication across organisation requires motivation. Important network structures increasing that motivation are strong ties. What this leads to is that weak ties promoted by, e.g., Granovetter (1973), are not a sufficient precondition for knowledge transfer: in some situations strong ties are required. Thus, in an organisation with separated groups and at the most weak ties between those groups, ability to transfer complex knowledge can be significantly hindered. However, the type of the knowledge has great significance: the effect described is not precent when the knowledge is simpler and can be, for instance, written down as instructions. Further support for the importance of strong ties between groups inside organisation can be found in interorganisational conflicts: there is association between strong ties and lack of conflicts between groups inside an organisation (Nelson, 1989).

When there are hindrances in the distribution of information, it is likely that finally there are differences in information and knowledge individuals posses. It could be expected that this leads to both inequality and increasingly conflicting

views. To reduce such development, it should be ensured that individuals across an organisation adopt approximately similar ideas. This is naturally achieved by individuals having ties to a fairly similar sets of other individuals, i.e. structural equivalence (Burt, 1987). However, when individuals are distributed in externally poorly integrated groups they have ties to a significantly dissimilar sets of other individuals, i.e. there is low structural equivalence. Thus, fragmentation to internally similar and externally dissimilar groups leads to inequality and conflicting views.

### 3.3 Is social network fragmentation likely?

In any risk both magnitude of the potential loss and the probability factor in. That is why after discussing the potential problems, one should take into account the probability. Related to this subject, Granovetter (1973) poses a question about certain community: "Could the West End's social structure have been of this kind?", referring to the idea that the community would be highly fragmented. One approach for assessing the probability of an organisation becoming fragmented is to consider the willingness of individuals in the organisation to form ties outside their most dense clique.

By definition, in a clique, all individuals are connected with each individual in the clique (Scott, 2000). As the size of the group forming the clique increases, so does the amount of ties a member of the group maintains. Granovetter (1973) brings up the possibility that having a large amount of strong ties inside the clique may require or end up taking such a large portion of one's time that it is not feasible to maintain or form other ties outside the clique. Also Dahlander and McFarland (2013) support this view when it comes to the formation of new ties: individuals with a large number of ties to maintain are less likely to form new ones. It is, however, possible that time constraints apply only when individuals have large enough networks. It has been observed that people devote more time to communication when their network increases up to approximately 40 contacts, after which they begin to devote less time for each contact (Miritello et al., 2013).

To further investigate the restriction of the amount of ties one can maintain, there

is an upper limit of approximately 150 that is caused by the structure of the human brain (Dunbar, 1993). That 150 is naturally not a restriction that would be clearly met in most organisations or in most cliques but more of a reminder about the fact that organisation members as human beings have to optimise the amount of ties they can "spend" in any organisation.

As Granovetter (1973) suggests, weak ties are likely the ties that finally determine if a network becomes fragmented. The reasoning is that when there are few or only a single tie bridging between two groups, that tie is very likely a weak tie. This is why one should especially concentrate on weak ties when studying the likelihood of a network becoming fragmented.

Research has observed that integration in an organisational social network is a self-accelerating feature. This is due to the phenomenon where existing ties from two individuals to a third person increases the likelihood of a tie also between those two individuals (e.g. Kossinets & Watts, 2006; Martin & Yeung, 2006). In other words, if there is a tie both from A to C and from B to C it is likely that there is also a tie between A and B. From the perspective of network fragmentation, it should be expected that the relationship exists also in the opposite direction: when the amount of ties connecting individuals in different groups decreases simultaneously decreases the likelihood of new ties forming or old ties remaining between those groups. Furthermore, as described above, if there is only a single tie between two groups it is improbable that this tie would be a strong tie (Granovetter, 1973). Thus, fragmentation is also a self-accelerating process.

*Tie persistence*

As fragmentation is the lack of ties it increases as tie persistence decreases. Factors affecting tie persistence are for instance the strength and complexity of a tie, maintained proximity between individuals, and the sense of shared history. To elaborate more, some existing ties can be seen as obligations to be maintained by individuals because of the strength of the tie and the history it is related to. Additionally, existing ties can be a complementary resource for an individual. On the other hand, for an old tie to persist, it is not necessary that the tie would bring any new value or

opportunities for the individuals involved. (Dahlander & McFarland, 2013)

Based on that knowledge about tie persistence, it can be examined, what is the likelihood of a tie persisting between individuals who have been working together in a group: It should be expected that high level of integration inside groups increases the initial tie strength and sense of common history, thus improving tie persistence. However, when groups are clearly separated from each other the distance is long between individuals who have moved to new groups. Thus, the perspective of tie persistence does not provide clear knowledge of whether fragmentation is likely or not.

While the sense of shared history predicts better tie persistence, similar effect has been observed purely based on the length of the history. That is, when individuals have been in a group together the longer the group has endured the better the tie between those individuals persists (Martin & Yeung, 2006).

While the features of a tie itself affect its persistence, so do the individuals connected by the tie. Namely, experience in maintaining ties that are important, persist poorly and change in their nature is related to ability to maintain bridging ties (Burt, 2002). However, based on Burt's results the effect of experience is not high enough to overcome the significant decay of ties present in his study.

Clearly evident from the research of, e.g., Dahlander and McFarland (2013) and Burt (2002), is that ties don't necessarily persist. Furthermore, research shows that the ties most prone to decay are bridges (Burt, 2002) – the ties that are most important for reducing fragmentation. Thus, even if the social network of an organisation is not fragmented at a given moment its general tendency is to go towards fragmentation; if no opposing forces are forming new bridges.

As mentioned earlier, it is typical in social networks that there is homophily that affects the structure of the network (e.g. Rogers & Bhowmik, 1970; McPherson, Smith-Lovin, & Cook, 2001). That should be considered as one factor affecting fragmentation in networks: If the organisation outside a group consists of very similar individuals with the members of the group, homophily could be expected to increase the likelihood of there being ties between the group members and the outside organisation. For instance, if the organisation consists of people with similar

age, education and interests homophily can increase the formation of ties between all individuals regardless of the group structure. On the other hand, if all the groups in an organisation are very specialised and consist of individuals with clearly different backgrounds compared to other groups, there is smaller likelihood that there are ties between members of different groups.

Furthermore, homophily, too, affects tie persistence and ties between similar individuals are more likely to be maintained (Hallinan & Williams, 1989). In a group setting, similarity with other group members increases likelihood of maintaining a membership and increases the duration of that membership (McPherson, Popielarz, & Drobnic, 1992; Sparrowe & Popielarz, 1995). McPherson et al. (2001) present that possibly the existence of some ties depends on the similarities between individuals who the surrounding organisation and environment cause, and thus if the organisation or other environmental factors change the ties are more unlikely to be maintained. It is clear that such situation occurs when members of a same clique move to new groups. However, this could also cause the disconnection of bridges (i.e. ties between cliques) if the tie has been formed or is maintained mostly due to environmental similarities (e.g. the same physical location for work). This would suggest that bridges can be surprisingly fragile and making organisational or environmental changes can unexpectedly lead to increase in fragmentation.

Since homophily brings similar individuals together and increases their integration and increases tie persistence, it could be argued that homophily is the force keeping groups together. However, research suggest that the structure of the social network in a group affects also how it stays together. This is because ties are more likely to persist when the individuals involved are both connected with a third individual (Martin & Yeung, 2006). This is known as structural embeddedness. If groups are described as cliques, their structural embeddedness is high by definition since every dyad has at least one and most likely multiple third parties to whom both individuals in the dyad are connected. When discussing the persistence of ties formed in a group, it can be expected that those ties persist better than other ties since it is more likely that there is structural embeddedness. Thus, based on the results of Martin and Yeung and consideration of group structures, it is reasonable to suggest that

structural embeddedness reduces the fragmentation over time in highly group based organisations.

Both Ancona and Caldwell (1992) and Reagans et al. (2004) discuss about approaches that utilise the benefits that are related to homophile. Particularly, their idea is that demographic diversity inside a group would decrease the likelihood of fragmentation since there would be more homophily between members of the group and different individuals outside the group. However, one issue mentioned by (Reagans et al., 2004) is that homophily is not necessarily a strong enough factor in the structure of a social network and thus the approach described above may be rather ineffective. Nevertheless, if long-term effects are considered, having diverse groups can be the most successful approach. As described earlier, individuals with diverse networks learn to better communicate with individuals unlike them. Thus, high diversity inside groups can be used as a tool to help individuals become more able to communicate and transfer knowledge despite diversity (Reagans & McEvily, 2003).

One more aspect affecting tie persistence is distance between individuals. (Martin & Yeung, 2006) The suggested reason is rather intuitive: longer distance increases the effort required to maintain a tie. However, Martin and Yeung (2006) found an interesting relationship between distance, tie persistence and tie strength. Their conclusion is that strong ties are the most prone to decay when distance between individuals increases, while weak ties can bear the added difficulty better. Thus, while distance affects tie persistence in general it should not be a significant factor in network fragmentation. This is because weak ties are the most important in reducing fragmentation and they should remain well in spite of distance.

## 3.4 Reconnecting old ties

One perspective to the fragmentation of the social network of an organisation is how well individuals are able to form ties when it is necessary. If the formation of ties is effortless, the fragmentation can be reduces when new situations arise. This is why the ability of individuals to reconnect old ties does matter. Restoring old ties is

especially important in the research setting of this study because the network of old ties may be significantly denser than the network of active ties.

In the subject of restoring ties, the concept of dormant tie is important. Dormant ties are connections between individuals who have had a strong or weak tie previously, but who have not communicated or contributed to each other for a significant amount of time. The characteristic requirement for a dormant tie is that there is a possibility that the individuals contact each again. (Levin et al., 2011) In the context of empirical research, observing dormant ties is naturally more difficult than observing weak or strong ties since the individuals involved in dormant ties don't indicate that they are communicating with each other actively and may even have forgotten that the tie exists.

In this study, it has been described that lack of ties between separated groups causes especially hindrance in the knowledge distribution and poor utilisation of useful knowledge in an organisation. Levin et al. (2011) have shown that dormant ties are effective in eliminating these issues. They found that individuals can reconnect and that reconnected ties were "efficient and effective in providing useful knowledge". It is especially significant that after reconnecting the old tie, the individuals benefited from the former strength of the tie in such manner that, for instance, their trust and shared perspective still existed. It can be even argued that after reconnecting dormant strong ties, they had the beneficial features from both strong and weak ties: there is still trust and shared perspective left (typical in strong ties) but also they can be described having novelty and efficiency (typical in weak ties).

In an organisation where most individuals are involved in cliques consisting of strong ties, significant investments (at least in time) are involved to initially form each clique. Thus, losing the strength of these ties is a form of loss for the whole organisation. An important finding is that dormant strong ties have the characteristics of strong ties still after reconnection (Levin et al., 2011).

Based on the known benefits of reconnecting dormant ties, it would be easy to conclude that maintaining ties is inefficient since most ties can be reconnected even if there has been a long time without any contact. However, this has it is

downside: investments have to be done to build one's network and networks cannot only function as sources of benefits. (Levin et al., 2011) For instance, from the perspective of an individual, it might feel unjustified if you don't have opportunities to form and strengthen ties with your working mates but people in the organisation frequently request your working time to help them.

# 4. Methods and data

## 4.1 Data

This study uses work time reporting data as it is only dataset. It should provide the general understanding about who has worked with whom. It also provides granular information about the timing of two people working together and the length of their collaboration. However, it is not able to explain communication and collaboration that is not billable or is not recorded in work time reporting for other reasons. Also, work time reporting doesn't answer the question whether the tie has been maintained after the formal collaboration has ended. These restrictions are accounted for in the usage of the data and certain data processing methods are utilised to partially overcome these issues. In this section, the dataset is described. This includes, among other matters, how the data is acquired and how it is processed.

*Work time reporting*

The employees in the company that is the subject of this study record most of their work in a work time reporting software. The records are done for one day at a time and the specific information included in the records are a code for the project and the amount of work done during the day. Depending on the employee the records can be filled as often as daily but at least once a month. The software itself adds a date for the record. For the purpose of this study, the records are exported in such a way that

the complete work history is presented for every individual. The work history data contains an identifier for the individual, all the projects the individual has worked in since 2008, and the exact dates the individual has worked in those projects.

As described in the introduction, work in the studied company is done in teams and one project is done by one team. Most of the teams work colocated in customer premises. The length of the projects varies from couple of weeks to several years. In case of multi-year projects often the formation of the team experiences some changes where new members join the team and old members leave and join new projects. The work time reporting reflects these projects and thus a project in the work history of an individual should be regarded as a membership of the team doing the project. In other terms, people having the project in their work history with overlapping dates have done work together in the same team.

The data is sufficiently reliable description about the work history of a given person since it is used as the basis of billing in the organisation and thus special effort is seen to ensure the reliability of the data. The level of granularity in the data is optimised so that both false positives and false negatives are minimised: people reporting work time for the same project are most likely working for the same customer and in the same premises, while it is unlikely that people reporting time for different projects would work together.

In total the data consists of close to 500 individuals and close to 1000 projects (internal work excluded). The amount of individuals who have ever worked in a project is on on average approximately five individuals with standard deviation of approximately seven. As expected based on previous research about community sizes (Guimera et al., 2003; Gleiser & Danon, 2003), project size distribution is significantly skewed: most projects are smaller than average but few projects are multiple standard deviation larger than average.

As there are both directed and undirected ties in graphs, connections can be represented between individuals both when the relationship is one-sided and when the relationship is reciprocal. If we don't want to or can't identify the direction of the tie, the ties can be considered as bonded ties (Hanneman & Riddle, 2005). Since the data at hand indicates only participation in a project and doesn't indicate personal

connections the direction of the ties between teammates can't be determined. Thus, the ties in the network are handled as undirected.

Social ties are seldom discrete but tie strength is a continuum from very weak to strong. However, often it is useful to reduce social network ties to discrete values (i.e. tie exists or doesn't exist) using set cut-point for tie strength (Hanneman & Riddle, 2005). For that reason the work time reporting data was processed in a way that the cut-points are based on the amount of days that two individuals have worked together. Murray, Rankin, and Magill (1981) describe self-reported contact frequencies for perceived tie strengths. Based on the frequencies they present, from the ties that are considered strong approximately 50% have been in contact more than two times per week. Even though strong ties may also involve tremendously less contacts, only being in contact a couple of times a year or a couple of times a month doesn't separate strong ties from intermediate ties in their data. Findings in a study by Reagans and McEvily (2003) provide further support for the results above.

Based on the reasoning above, in this study two times per week as a contact frequency is set as the threshold for strong ties. This selection can be further supported by the restriction that the data has to be handled as a snapshot from certain time intervals and thus it has to be ensured that the individuals involved in the tie have been in frequent contact at least during that time. To further elaborate, utilising snapshots means that a time interval is selected and the work history of every individual is cut so that only the history during that selected time is considered. In other terms the snapshot captures the contacts of the network at some specific point in time. For strong ties the time interval used for the snapshot is set at two months to ensure that multiple-weeks-long vacations or illnesses don't reduce the potential time spent together with a coworker more than 50%.

It is necessary, for this study, to finding both the cliques and the ties outside cliques, i.e., weak ties. This is because with that information one can see what kind of structures the organisation has formed for collaboration. That is, whether the work occurs mainly in tightly knit groups or is there a much more distributed and sparse network through which individuals communicate. That is why only observing

the strong ties is not sufficient.

To use the work time reporting data also for investigating weak ties, another cut-point has to be set. In the frequencies from Murray et al. (1981) it can be observed that most weak ties are indicated to involve contacts less than once a year. However, it is also mentioned in the article that there may have been times with more frequent contacts than what is measured. That is why it is justified to expect more frequent contacts at least at some point of time even from weak ties. For this study the threshold is thus set to two days of work time reported to the same project at the same time during a period of one year.

From the data, both company internal work and non-project work are excluded. In this context, internal work stands for projects and tasks that are not paid by a customer and are required by the studied organisation itself. This exclusion is done to ensure that two people reporting work time to the same project at the same time indeed have worked with each other. The restriction excludes certain positions from the network. Nevertheless, this is not an issue since this study is most interested in individuals who work in non-hierarchical independent teams in customer projects and those teams are affected less by the exclusion of company internal work.

A traditionally used method of social network analysis, i.e., an employee survey (Guimera et al., 2003; Tyler et al., 2003), only considers the current state of the network. However, social networks also have a time dimension, i.e., they change in structure over time (Duan, Li, Li, & Lu, 2012). In the case of the studied organisation both the projects and individuals working in the projects change. Moreover, social networks have memory in such a way that some portion of ties that have existed in history can be reconnected with ease. (Levin et al., 2011) To account for the dynamic nature of the social network, snapshots taken on set points in time can be used (Nguyen, Dinh, Xuan, & Thai, 2011). For the purpose of this study, multiple snapshots are taken from the work time reporting data.

The snapshot time intervals are selected separately for strong ties and for all ties. As mentioned above, strong ties require two month snapshots. To avoid irregularities in work time reporting during vacation seasons, the snapshots are positioned from February to March and from September to October. For the purpose of widening

the sample set, five different periods are used from Fall of 2015 to Fall of 2017. The snapshots used for networks with all ties are full one year periods based on calendar years. The ensure proper overlap with the two-month periods, years 2016 and 2017 are selected.

One way of dividing ties into weak and strong ties in work related contexts is to rely on two complementing aspects: if the individuals know each other's work and if they know each other personally. When both these requirements are fulfilled, the tie can be considered strong. (Granovetter, 1974) Work time reporting clearly indicates when two individuals most likely know each other's work, and requiring a large enough amount of days working together improves the likelihood that those individuals know each other also personally. Thus, work time reporting can be used in investigating strong ties in an organisation.

When weak ties are considered, it is not required that individuals work together since there is a wide variety of other ways for forming ties in an organisation. Thus, this data can't be used as the only source for finding weak ties. However, people working together most likely form at least a weak tie and that is why work time reporting can explain a subset of weak ties.

As a conclusion, the purpose of the work time reporting data is to mainly be used when analysing the structure of teams in the organisation. In other terms, the important question is, what kind of structures strong ties form in the organisation. Furthermore, the data can be used for analysing cross-organisational weak ties, i.e., ties between teams. The graphs based on the data are presented in appendix B.

When the restrictions imposed on the ties are taken into account some individuals are left completely without ties. These individuals are not included in the analysis since that wouldn't add meaningful information about the structure of the graph. This is why the final graph consists of fewer nodes than the data has people. Further reduction to the amount of nodes is due to the exclusion of company internal work. The Table 4.1 shows the amount of nodes and ties in the resulting network.

Even though it is necessary to have cut-points for tie strengths for certain types of analysis, for some network analysis methods that is not required. An application for "raw" continuous tie strength measures is network constraint. For that application

**Table 4.1.** Network size including amount of nodes (i.e., individuals) and edges (i.e., ties between individuals)

| Ties included | Time period | Nodes | Edges |
|---|---|---|---|
| Strong ties | 09/2015 - 10/2015 | 179 | 452 |
| | 02/2016 - 03/2016 | 193 | 440 |
| | 09/2016 - 10/2016 | 220 | 565 |
| | 02/2017 - 03/2017 | 221 | 613 |
| | 09/2017 - 10/2017 | 246 | 821 |
| All ties | 2016 | 306 | 2254 |
| | 2017 | 369 | 2967 |

the data presents the actual amount of days the two individuals have worked in the same project at the same time. Further explanation of calculating network constraint is described in the next section.

## 4.2 Analysis of work time reporting

For analysing the network based on work time reporting data, a software called Gephi (Bastian, Heymann, & Jacomy, 2009) is used. Most of the variables described below are computed using algorithms implemented in the software. Furthermore, the network graph visualisations (see, e.g., Appendix B) are rendered using the layout and visualisation features in Gephi. Layout algorithm used is ForceAtlas2 (Jacomy, Venturini, Heymann, & Bastian, 2014). The algorithm is adjusted to separate communities from each other while keeping disconnected parts relatively close to the core network.

Community structure being an important feature of social networks (Guimera et al., 2003), detecting communities in social networks is a significant step in understanding the network. This study utilises an algorithm from Blondel, Guillaume, Lambiotte, and Lefebvre (2008). To unravel how typical the community structure is the sizes of the communities discovered are compared with the ones presented by Guimera et al. (2003) and Gleiser and Danon (2003). Furthermore, recognising community structure helps in visualising the network (Newman & Girvan, 2003).

In typical organisations, the distribution of community sizes is observed to follow

power law (Guimera et al., 2003; Gleiser & Danon, 2003). Following this distribution there should not be a typical sized community and purely observing the average community size hardly helps in understanding the community structure of the network (Clauset, Shalizi, & Newman, 2009). Thus, community sizes are fitted to power law to discover both the exponent, the quality of the fit and potential cut-off points. For power law fitting a Python programming library from Clauset et al. (2009) is used as a tool. Power law probability distribution being $p(x) \propto x^{-\alpha}$ the tool provides both $\alpha$ and the error $\sigma$. This enables the intended comparison with results from previous research.

As literature suggest network density and network constraint are characterising features for a social network (Reagans & Zuckerman, 2001; Rosenthal, 1997). Both are measured to understand the nature of the network at hand. For a network density is the proportion of existing ties from the ties that could exist (Balkundi & Harrison, 2006). Equation 4.1 presents density when the network has $g$ nodes and $L$ ties.

$$\Delta = \frac{L}{g(g-1)/2} \tag{4.1}$$

In social network analysis, it is not always the best approach to look at the network of an organisation as a whole. It may be more useful to do more fine grained analysis – for instance, to look at more subnetwork or clique level. (Provan & Sebastian, 1998) Just as a simple example, when calculating the density of a network, the result is the same for clearly dissimilar networks. One network can be highly fragmented with high density inside subnetworks and low intergroup connectedness while another could have loose integration across the whole network. For both networks, the ratio of the number of ties to the number of possible ties is similar but the organisations don't resemble each other considerable. Thus the density is calculated for both the whole network and communities recognised from the network.

Rosenthal (1997) describes constraint as the extent to which connections of individuals lead to a single other individual. What Rosenthal further explains is that constraint is related to the time and energy that is spent on one tie. To elaborate, an individual is highly constrained if she spends most of her time communicating with

people that only communicate with each other. On the other hand, the individual has very low constraint if she communicates with people of whom nobody knows each other. When an organisation is only reduced down to its social network calculating reliable constraint estimations is difficult since the time and energy spent on ties in the network can not be accurately taken into account. Thus, the work time reporting data is highly useful because it allows us to approximate how much time two individuals have spent communicating together.

The basis for constraint is then how great proportion of the time of an individual is spent communicating with another individual. That proportion can be denoted with $S_{ab}$ – $a$ being the individual under investigation and $b$ being her contact. Additionally, $a$ has other contacts $C$ (and $c_i \in C$) that $a$ spends time communicating with. The absolute communication between two individuals $a$ and $b$ is denoted with $s_{ab}$. Equation 4.2 describes the proportion of communication of $a$ with contact $b$ (from the perspective of $a$) (Gargiulo & Benassi, 2000).

$$S_{ab} = \frac{s_{ab}}{\sum_C s_{ac}} \tag{4.2}$$

If the data directly described communication between two individuals values for $s_{ab}$ would be effortless to get. However, since the data describes only work time spent in the same project that has to be used as proxy. For the purpose of calculating relative communication amounts it is approximated that $s$ stands for time spent together in a project. That approximation captures the situation where two individuals work in different sized projects. That is, the larger the project the smaller amount of communication there approximation predicts between two individuals since if $C^{(1)} > C_{(2)}$ then $S_{ab}^{(1)} < S_{ab}^{(2)}$. Furthermore, dividing work between projects is predicted also to lower amount of communication since if $s_{ab}^{(1)} < s_{ab}^{(2)}$ then $S_{ab}^{(1)} < S_{ab}^{(2)}$. The assumption of this approximation is that individuals work mostly similar shares of their work time in similar sized projects.

As described above, network constraint captures the proportion of communication that $a$ has with $b$ and simultaneously the proportion of communication that both $a$ has with $c_i$ and $c_i$ has with $b$. Most importantly it regards to what extent these communication levels are high at the same time. The formal description of con-

straint in the network of $a$ presented by $b$ is presented in equation 4.3 (Burt, 2009). Implementation of the algorithm is presented in appendix A.

$$r_{ab} = [S_{ab} + \sum_{C} (S_{ac} S_{cb})]^2 \tag{4.3}$$

Then, the full network constraint for an individual with ties to teammates $B$ is:

$$R_a = \sum_{B} r_{ab} \tag{4.4}$$

While some research (Reagans & Zuckerman, 2001; Reagans et al., 2004) has shown network density to improve team performance density is not the only neither the most precise measure to use for the integration of individuals in teams. For instance, density can be elevated following a high level of integration throughout a network while there is poor integration inside teams.

Since this study is especially interested in cliques in social networks, there is a more exact method of analysis that can be used alongside network density. The method (suggested by Krackhardt, 1999) is about identifying Simmelian ties in a network. That is, the network is searched for ties where two individuals are reciprocally connected and both connected similarly to a third person. After identifying these ties, they can then be used for further identifying cliques. However, also the opposite analysis should be done: identifying those individuals who don't have Simmelian ties and all the collaboration that is done outside cliques.

To simplify, Simmelian ties are the ties in graphs that form triangles, i.e., three nodes connected with three ties. Another, arguably a more well known, network feature closely related to triangles is clustering. Watts and Strogatz (1998) describe clustering as the extent to which the contacts of an individual are connected to each other. They also refer to clustering as the cliquishness of a (local) neighbourhood. The actual measure that is used for clustering is called clustering coefficient. The relationship with clustering and triangles is that clustered network consists of triangles to a large extent (Latapy, 2008): if the contacts of an individual are also contacts of each other these three nodes form a triangle. In this study, the triangle listing algorithm by Latapy (2008) is used for calculating clustering coefficients.

As Watts and Strogatz (1998) describe the calculation of clustering coefficient: in a network with nodes $A$, for node $a$ with $B_a$ neighbouring nodes, the maximum amount of ties between the neighbours is $p_{max} = B_a(B_a - 1)/2$. Then $C_a$ is the proportion of actual ties $p_a$ between the neighbours from the maximum $p_{max}$. Thus, clustering coefficient $C$ is:

$$C = \frac{1}{A} \sum_{A} \frac{p_a}{B_a(B_a - 1)/2} \tag{4.5}$$

When the social network of an organisation has completely disconnected parts the phenomenon is called fragmentation (Provan et al., 2005). In this study, fragmentation is measured using both the numbers of disconnect network parts and the sizes of those parts.

The degree of nodes and its distribution is a simple measurement of a social network. The distribution is known to follow power law (Miritello et al., 2013; Albert & Barabási, 2002). In this study, the degree is fitted to a power law distribution to investigate whether to network is a scale-free network like social networks typically are (Watts, 2004). Furthermore, a motivation to study the degree of nodes in a social network is that the degree is related with both benefits and hindrances in the individual level (Adler & Kwon, 2002; Mayhew & Levinger, 1976).

As a final form of analysis, the data is investigated from the point of view of cut-points and transforming interval measures to binary. As described about the processing of the data, cut-points are set to enable the use of tools developed for binary measures in a continuous dataset. As Hanneman and Riddle (2005) describes the selection of cut-points is of great significance when transforming continuous measures to binary. Their argument is that if cut points are not carefully considered the phenomena observed may exist only due to a particular cut-point. However, also the opposite should be considered: if the selection of cut-points is influenced by the effects they have on the resulting data there is a risk of introducing bias to the results. For instance, increasing cut-point excludes ties from the network and thus may steadily decrease network density and clustering coefficient. Also, since most likely weak ties are excluded first the remaining network may seem unrealistically

fragmented if cut-point is increased with a specific target in mind.

A major issue with work time reporting data is that cut-points have to be determined and thus conscious decisions have to be made about required tie strength and measured intervals. To quantify the significance of these decisions the effects of those parameters are investigated. This is done by presenting certain network variables as a function of both tie strength and measurement interval. The most important feature this analysis is concerned with is non-linearity in the function. If the function is highly non-linear, small changes in the cut-point has substantial effect on the outcome variables and the structure of the network. This would indicate that the data is prone to bias induced by data processing methods.

# 5. Results

## 5.1 Community structure

Table 5.1 describes the community structure of the network superficially. As can be expected, the amount of communities increases for every snapshot. Meanwhile, the average size of community is approximately stable.

Because of the lack of descriptiveness of the average community size it is highly interesting to investigate power law fit of the data. Since the community structure doesn't vary significantly between snapshots the snapshots with most communities are selected for further studying. Figure 5.1 presents the distributions.

The figure indicates fit to power law with $\alpha = 2.0$ for the network of only strong ties. When comparing with results of Guimera et al. (2003) and Gleiser and Danon (2003),

**Table 5.1.** Community structure

| Ties included | Time period | Communities | Community size mean | stdev |
|---|---|---|---|---|
| Strong ties | 09/2015 - 10/2015 | 30 | 6.0 | 4.5 |
| | 02/2016 - 03/2016 | 37 | 5.2 | 3.4 |
| | 09/2016 - 10/2016 | 38 | 5.8 | 4.9 |
| | 02/2017 - 03/2017 | 40 | 5.5 | 4.3 |
| | 09/2017 - 10/2017 | 44 | 5.6 | 5.2 |
| All ties | 2016 | 30 | 10 | 5.1 |
| | 2017 | 35 | 11 | 5.8 |

there is substantial difference: their observed $\alpha = 0.48$. This can be interpreted so that with the distribution with $\alpha = 2.0$ the probability of finding substantially larger communities than the smallest community is smaller than with $\alpha = 0.48$. Both of the referred studies also observe a cut-off point in community size $s \approx 200$. In the network under observation, the cut-off point is in $s = 17$. Because the networks under comparison are clearly different in network sizes comparing the cut-off points directly may not be fruitful.

However, it can be concluded that the typical cut-point is observable also in the network at hand. The cut-off point is earlier, though, compared to the size of the whole network: $s = 17$ from the whole network of $N = 246$ vs. $s \approx 100$ with $N \approx 1000$ (Guimera et al., 2003). One potential contributor to this difference is that in the previous studies the communities are hierarchical, i.e., there are communities of communities. Because of the lack of such hierarchical communities in the network of this study, even the largest communities are relatively small.

When the network with all ties for 2017 is observed, the distribution doesn't follow power law. That result indicates that there is a typical size for a community in the network and most of the communities have their sizes relatively close to the average. However, it should be noted that the variation is relatively large: community size standard deviation is approximately half of the mean.

## 5.2 Network density

The network density metrics in Table 5.2 are in line with general social network structure. It is typical for tie to concentrate inside dense groups and on the other hand to only sparsely occur between those groups (Newman & Girvan, 2003; Girvan & Newman, 2002). Even if the communities inside the networks were discussed before, investigating the densities highlights this feature even more. If the networks with all ties are considered, there is a difference in magnitude between the density of the communities and the density of the entire network.

If the perspective is narrowed down to strong ties, the cliqueness of the network becomes obvious. The network consists of communities that are close to completely

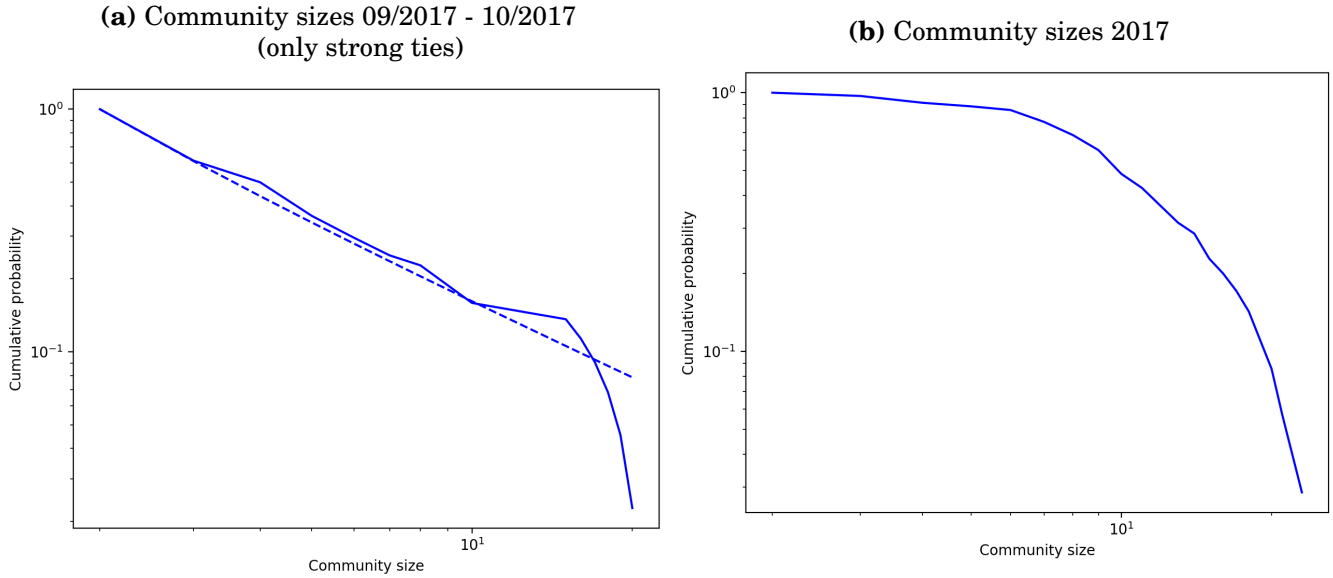



**Figure 5.1.** Complementary cumulative probabilities for community sizes in log-log scale. Continuous line represents the actual community sizes. Dotted line represents the complementary cumulative distribution function for power law fitted to the data. $p(x) \propto x^{-\alpha}$; $\alpha = 2.0$, error $\sigma = 0.15$. Because of poor fit the distribution function is excluded from the right graph with all ties.

**Table 5.2.** Network densities for all time periods. Full network densities are separated from community densities (for which mean and standard deviation are reported).

| Ties included | Time period | Network density | Community density mean | stdev |
|---|---|---|---|---|
| Strong ties | 09/2015 - 10/2015 | 0.028 | 0.842 | 0.221 |
| | 02/2016 - 03/2016 | 0.023 | 0.841 | 0.201 |
| | 09/2016 - 10/2016 | 0.024 | 0.855 | 0.229 |
| | 02/2017 - 03/2017 | 0.025 | 0.866 | 0.194 |
| | 09/2017 - 10/2017 | 0.027 | 0.897 | 0.177 |
| All ties | 2016 | 0.048 | 0.682 | 0.227 |
| | 2017 | 0.044 | 0.701 | 0.202 |

integrated. If it is assumed that these cliques are the cores of teams, the data suggest that there are individuals "surrounding" the core teams weakly tied to the team members. This is visible in the decreased community internal density in the network with all ties. Furthermore, the data would suggest that there are individuals with weak ties connecting team together since the number of communities is smaller in the network with all ties. The smaller amount of communities necessitates that some of the strong tie communities are combined together as communities with strong ties in the core and weak ties spanning the larger group of people.

As can be seen in both Table 5.2 and the histograms in Figure 5.2, weak ties are distributed more evenly than strong ties. Especially in the histogram it can be observed how strong ties form almost exclusively tight communities but weak ties balance the density difference between the whole network and communities and also form less tight communities. This illustrates how well the organisation at hand supports the theory by Granovetter (1973): seldom strong ties span between communities but those ties are most often weak ties. It can be even argued that the project and team structure visible in the graph increase the likelihood that strong ties are not formed between communities.

**(a)** Community densities with only strong ties

**(b)** Community densities with all ties

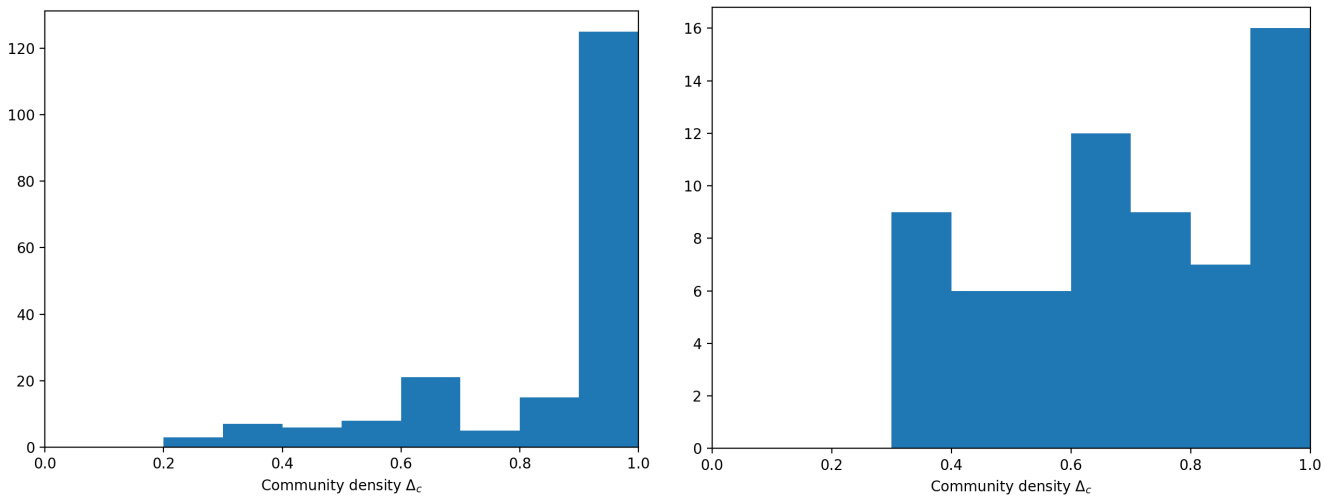



**Figure 5.2.** Network community density histograms

## 5.3 Clustering

The clustering coefficients in Table 5.3 provide clear insight into Simmelian ties in the network: among strong ties at least approximately 90% are Simmelian ties. This indicates that strong ties are not "wasted" on dyadic connections but they are in tightly connected communities. Thus, the tie structure is optimal to drive teamwork with fewer hindrances from conflicts, higher level of equality and better incentives for investing in the success of the team (Krackhardt, 1999, 1998). As comparison Krackhardt (1999) had partially similar and partially different results. In his study, some strong ties spanned over the whole organisation but there were also Simmelian ties inside multiple communities.

When studying purely clustering coefficients in figures 5.3 and 5.4 three distinct features can be found: uniform distribution, large range, and range of level of clustering inside communities. First of all, the clustering coefficients are partially concentrated in the higher end (from 90% clustered to fully clustered). There is also lack of individuals with low clustering (20% clustered or less). However, most of the mass is distributed evenly in the middle range (from 20% to 90%). Since lack of clustering is an indication of better access and more structural holes, it suggests

**Table 5.3.** Network clustering

| Ties included | Time period | Clustering coefficient |
|---|---|---|
| Strong ties | 09/2015 - 10/2015 | 0.87 |
| | 02/2016 - 03/2016 | 0.87 |
| | 09/2016 - 10/2016 | 0.84 |
| | 02/2017 - 03/2017 | 0.85 |
| | 09/2017 - 10/2017 | 0.90 |
| All ties | 2016 | 0.60 |
| | 2017 | 0.64 |

advantages to the individual holding the position (Burt, 2009). This distribution indicates that there are no individuals who would be substantially better connected than others in the network: there are always other organisation members who have nearly a similar position. Furthermore, even the majority of the network is never too far away from the "elite".

Even if the distribution is uniform for most parts with little concentration the distribution has still noticeably wide variation. That result indicates that there are large differences between some individuals: at one end organisation members work in highly integrated teams while at the other end individuals have ties that span around the network each providing more new information and access. When further analysed it is reasonable to suggest that the differences in the clustering of individuals' neighbourhoods are due to the difference in the work individuals do. The most common setting is a team where members are mostly working with each other. On the other hand, there are individuals who work with a larger more loosely connected set of people.

Furthermore, it should be noted that the ties in the network are from one-year period and thus it is not necessary to work with a large group to gather great amount of weak ties. It is equally possible that the individuals with less clustering have worked with small teams but changed the team multiple times during the year. In contrast, the individuals with high (or full clustering) have necessarily worked with the same group of people the whole year. That can be even used as an indication of length of the projects in the organisation: there is a large number of individuals who have most likely changes projects during the year but also there are communities

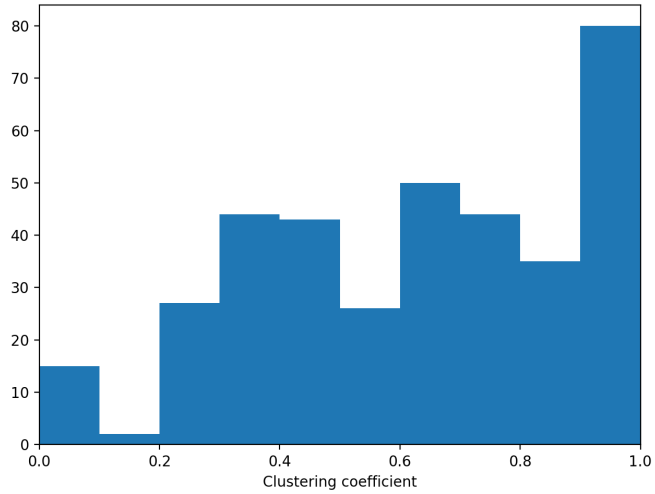



**Figure 5.3.** Clustering coefficients for 2017 network of all ties

(i.e. projects) that have met only a little change during the one-year period.

The distribution of clustering inside communities can be easily observed from the graph on the left side of Figure 5.4. Inside communities there is also visible variation in clustering – as there is in the whole network. One end in the distribution of clustering in communities is formed by individuals who have high clustering. Those individuals are connected to other team members who are then connected to each other. The team members at hand have also stayed in the same team for the whole year. On the other end there are members in teams who have connections to a team to increase their clustering but meanwhile they have connections to individuals around the organisation decreasing clustering of their network.

With further analysis of the network graph, certain patterns can be found in the connections of these individuals. Some have large amount ties to two communities. One explanation for this is change in project during the year. Second visible pattern is that there are individuals with connections to multiple highly clustered communities. This may be due to multiple changes in projects during the year but as well it can be due to participation in multiple projects as a specialist or facilitator in some specific field.

The best understanding about individuals working in multiple projects can be achieved investigating the networks with only strong ties. They reveal the indi-

viduals who are truly connected to multiple cliques in a small timeframe. The necessary data is not included in this study, though, for privacy reasons. Based on the data, few individuals can be found that truly are connected to multiple communities simultaneously. Thus, it can be concluded that most of the weak ties from one individual to multiple communities are due to changes in projects. However, working with multiple projects simultaneously does lead to fewer days spend with any given teammate and thus that collaboration appearing in the network of strong ties becomes more unlikely.

The "dilution" of ties encourages a more granular analysis of the network where the ties of intermediate strength are considered. In this study, the intermediate tie strength stands for ties that are not considered strong in the initial data processing described earlier but that still involve considerably more contact than weak ties. Such network including ties of intermediate strength is visible in the right side of Figure 5.4. The graph supports the fact that individuals connecting highly clustered cliques have weaker ties. It should be noted, however, that even during the shorter two-month timeframe there may be individuals who have completely changed projects and don't work with two communities simultaneously. Nevertheless, more thorough analysis based on the individuals and their concrete work time reporting during the time period reveals that there is indeed a set of organisation members working with multiple projects at the same time. Thus, it can be concluded that some ties are bridging over large structural holes in the organisation.

## 5.4 Network constraint

In this part of results both the empirical analysis based on the work time reporting data and measures from previous research are considered. The role of the empirical data is to provide information about the state of the studied organisation. The measures from previous literature are required for providing some points of reference for the otherwise arbitrary network constraint numbers.

Network constraint is shown for the corresponding periods as all the other measures. The results are visible in Table 5.4. It is important two distinguish the periods

**(a)** Clustering in network in 2017

**(b)** Clustering in 02/2017 - 03/2017 with intermediate and strong ties

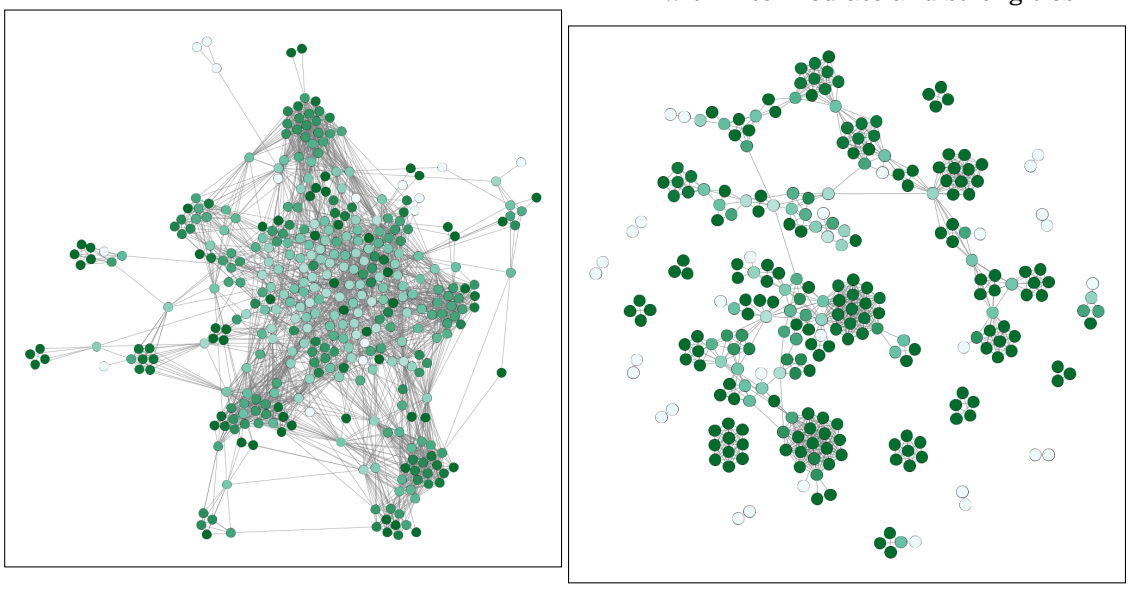


**Figure 5.4.** Clustering coefficients. The darkness of the node's colour indicates clustering coefficient for that node. Darker is more clustered. Due to the method of calculating the measures the nodes with only one tie are considered weakly clustered.

**Table 5.4.** Network constraints. There are no tie strength limitations but the constraint itself takes into account the amount of days two individuals have worked in the same project. The restriction is that only work reported for the selected period is taken into account. In other terms, the calculation is done as if the individual had only the connections that were active during the selected period and as if the contacts would have worked in a same project only during the selected period.

| Ties included | Time period | Constraint mean | stdev |
|---|---|---|---|
| Strong ties | 09/2015 - 10/2015 | 0.58 | 0.28 |
| | 02/2016 - 03/2016 | 0.60 | 0.27 |
| | 09/2016 - 10/2016 | 0.55 | 0.27 |
| | 02/2017 - 03/2017 | 0.57 | 0.28 |
| | 09/2017 - 10/2017 | 0.53 | 0.28 |
| All ties | 2016 | 0.39 | 0.22 |
| | 2017 | 0.36 | 0.22 |

in that table from the other tables: there is no restriction related to tie strength. Tie strength in other tables is concerned with during the data processing phase and it is based on the amount of days reported to the same project between two individuals. In the case of network constraint that is not necessary since the constraint itself depends on the time spent working together and thus takes it into account by itself. Nevertheless, the constraint results are reported for the same time periods as other measures to ensure better comparability.

With regard to the time periods, having the ability to compare them and observe the development of network constraint can reveal important aspects about the organisation. The most visible aspect in the constraint results is that the mean of the constraint of every network member decreases over time. The direction of the growth is similar in the full year periods. To get improved understanding about the development also the standard deviations have to be taken into account. The results show that the standard deviation has remained unchanged. Thus, the distribution has the same width but there has been a transition towards the lower end. From the histograms in Figure 5.5 can be seen that the distribution has remained similar to a certain extent but some weight from 0.4-0.65 area (in the first histogram) has moved close to 0.2 area (in the second histogram). This suggests that there have

not been radical changes in the collaboration patterns in the organisation; but a group of individuals have moved from an average constrained position to clearly less constrained position.

What can be interpreted from the network constraint histograms is that while the position of some individuals has changed the overall constraint has not decreased. The decrease in mean constraint would suggest that constraint would have decreased overall; however, that is not the case. As constraint can be described as the lack of structural holes (Gargiulo & Benassi, 2000), the decrease in constraint for some individuals is the result of them getting better access over structural holes, i.e., bridging. Burt (2009) shows, that these individuals with more bridges get advantage over other organisation members: for instance, their ideas are more often perceived good and valuable (Burt, 2004).

While bridging structural holes is advantageous to for the individuals who do the bridging it also benefits the cliques that are bridged together. The bridges are the weak ties that Granovetter (1973) discusses about: they keep the organisation from getting fragmented. They are the connections that enable asking for advice (Constant, Sproull, & Kiesler, 1996) and improve the transition of new ideas. However, the histograms in Figure 5.5 indicates that the bridges provide less benefits for the whole organisation than expected: Generally, the distribution has stayed the same showing that the majority of the organisation has not experienced significant change in their constraint. However, there are substantial points of concentration that have been below or near the middle of the distribution (around 0.3 - 0.6) in early 2016 and have moved towards the lower end (to 0.2) in late 2017. These individuals are the ones that have received the benefits of increasing range. These factors combined suggest that while some individuals have reached substantially less restricted position the rest of the organisation has stayed as constrained as before. In other terms, the bridges benefit only a minor part of the organisation.

Purely based on the histograms it is difficult to trace the underlying reason for this. Nevertheless, one possible scenario is that the bridges are so far away from most of the members of the organisation that the distribution of communication in the neighbourhood of these individuals doesn't change. To elaborate, if one forms a

bridge, a proportion of her communication is directed to a tie that does not create any constraint and her overall constraint decreases. If one's contact forms a bridge, part of the constraint created by that contact ceases to exist. However, if one's contact's contact forms a bridge it has a diminishing effect on the proportional communications of that contact. Thus, being two ties away from the bridge effectively makes that bridge useless for an individual; at least in the context of constraint measures. Furthermore, when the network has average path length of approximately three steps, one can already access major part of the network with paths that are two steps long, i.e., most members of the organisation are one's contacts or contact's contacts.

To summarise, one potential change in the organisation is that it has become more unequal. This is since the minority of organisation members have become less constrained while most have not received any benefits. Based on development visible in Table 5.4 it can be suggested that the organisation has become more unequal over time.

Purely by themselves, measures of constraint are not able to provide actionable information. The results become more useful when they can be compared with findings from other organisations. Naturally, it has to be taken into account that seldom organisations are fundamentally similar. However, previous research provides points of reference that can be used in this study to improve understanding about the meaning of the constraint measures.

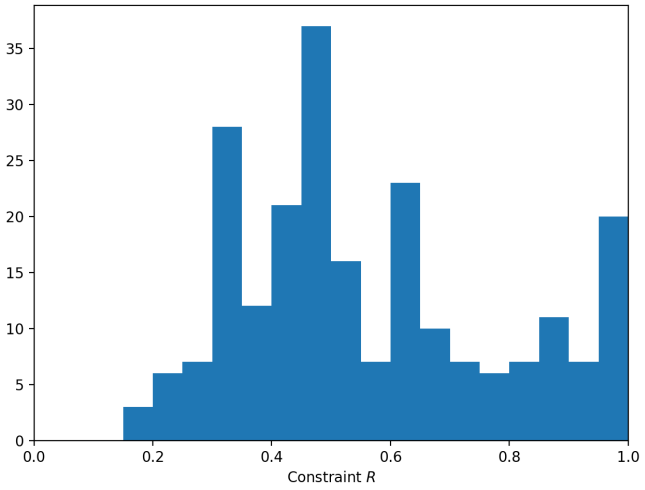
The first organisation to be used as a subject of comparison was studied by Gargiulo and Benassi (2000). The organisation is a multinational computer manufacturer and the authors of the study investigated the networks of 19 managers inside one suborganisation of the company. Their method of research was to gather information about the communication among the managers using surveys. By knowing how great amount of communication there was from one manager to the other they were able to utilise the same methods of calculating constraint that are used in this study. Their result for the constraint of the network of these managers is $0.22$. That is less than half of the constraint observed in this study in the two-month periods and under two thirds from the constraint in the full year periods (see Table 5.4). In other terms, Gargiulo and Benassi observed substantially lower constraint than what was

observed in this study. However, there are certain differences suggesting that this difference is partially presumable. The first difference is the sampling method: in this study the whole organisation is involved except the unconnected individuals while Gargiulo and Benassi restricted the selection to only managers in one unit in a vast organisation (with about 14000 members). It is reasonable to expect that the study doesn't capture the cliqued teams in which the managers may work but highlights more the occasional communication between managers that don't generally work together. Such communication could better avoid range-decreasing cliqueness and thus create less constraint.

The second organisation to be used as a subject of comparison is an contract R&D company that is described in a study by Reagans et al. (2004). The organisation is significantly more similar with the organisation observed in this study. The R&D company has a flat hierarchy and the members of the organisation work as project teams. The organisation had overall 113 members of whom 104 were involved in the study. The results of Reagans et al. indicate an average external range of $0.27$ and as constraint is the complement of range, network constraint is then $0.73$. To compare with the results of this study for two month and full year periods, the constraint in the R&D organisation is approximately 50% and 100% higher, respectively. Again, there are differences in research methods that partially explain that difference. Namely, the study of Reagans et al. collects network data in such a manner that potentially restricts the amount of ties that are reported by an individual and most importantly may highlight strong ties and exclude weak ties. Since weak ties are most important in bridging (Granovetter, 1973) the data collection method may increase the measured constraint of the organisation.

From the comparison to other organisations it can be concluded that the constraint results obtained in this study are not low but neither are they exceptionally high. Furthermore, the R&D company in the study of Reagans et al. (2004) is seemingly more similar with the organisation observed in this study. Thus, the organisation currently at hand can be considered having relatively low network constraint.

**(a)** Network constraints 02/2016 - 03/2016




**(b)** Network constraints 09/2016 - 10/2016

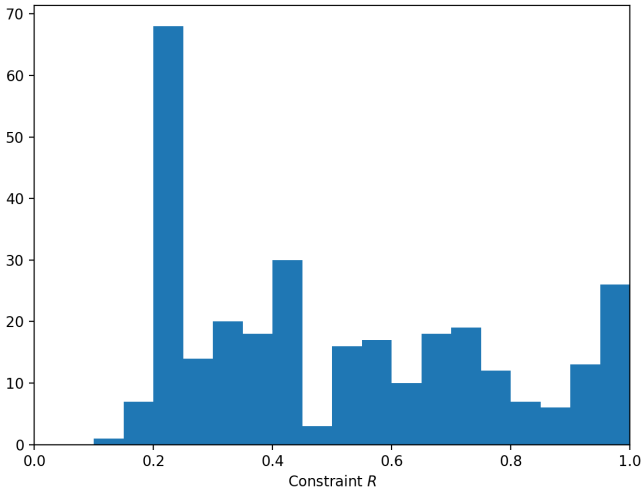



**Figure 5.5.** Constraint histograms. Individuals with constraint of zero are excluded since they are completely unconnected from the rest of the network.

## 5.5 Network fragmentation

Some communities are rather lightly connected to the overall network and some individuals inside cliques have large distances to remote parts of the network. However, neither of these features indicates the complete absence of ties between groups of organisation members. When a component is fully disconnected form the surrounding network the phenomenon is called fragmentation (Provan et al., 2005). The fragmentation of the network in the studied organisation can be rapidly noticed from Table 5.5. The networks purely formed with strong ties are highly fragmented while the networks with all ties don't suffer fragmentation.

With only strong ties, the case is not that the network would have divided into a handful of disconnected components. Mainly, neither are there smaller communities that would have separated themselves from a large core. Instead, the network consists of a large number of cliques that have no connections to each other. The smallest components include only two individuals but the largest components have more than ten members. When the amount of components is compared with the amount of communities (in Table 5.1) one can observe how the amount of components

is constantly slightly smaller or equal to the amount communities. This indicates that most of the communities are in reality disconnected components. Furthermore, there are components that combine some communities together. This can be also supported with the maximum sizes of components: the largest components consist of multiple communities. The network that has an indication about a core network is the period from September to October 2016 where there is one component with the size of 70 individuals. That is formed by four communities joined together. See Figure 5.6 for visualisation of this structure.

Even if the networks with strong ties are divided into unconnected components it can't be stated that the network would be clearly fragmented. This is due to the network with all ties that has no fragmentation. One approach to interpreting these observations is that naturally a network becomes fragmented when the cut-point threshold is increased until a great deal of the ties in the network are excluded. A more conservative suggestion would be that every individual don't know each other and there may even be individuals who don't have any third person to introduce them to each other. However, every person in the network has some path to any other person.

While the lack of fragmentation is encouraging, the separated components in the strong tie network introduce a shortcoming to the knowledge transfer in the network. The issue is that strong ties are required for transferring complex information (Reagans & McEvily, 2003) and the lack of strong ties between groups hinders the transfer of, e.g., new ideas, that are not as simple as mundane observations. It can be concluded that neither is the network completely fragmented nor is there strong integration across cliques.

A specific aspect of the organisation that is visible in the community structure of the strong tie network is the high level of clustering inside the components. In other terms, the separate components are not only individuals who have connections to one or two other individuals but group members who are all connected to each other. Figure 5.6 illustrates this well. The patterns the ties form support the original description of the organisation: independent teams are an integral part in the way the organisation is structured. However, one should also consider what is not

**Table 5.5.** Network components. Network component is a part of the network that has no ties to any other component in the network. Since the networks with all ties are fully connected the size of their only component equals to the size of the whole network. Individuals disconnected from the network are not included as separate components but are completely excluded from the calculations.

| Ties included | Time period | Components | Minimum size | Maximum size |
|---|---|---|---|---|
| Strong ties | 09/2015 - 10/2015 | 30 | 2 | 18 |
| | 02/2016 - 03/2016 | 37 | 2 | 13 |
| | 09/2016 - 10/2016 | 34 | 2 | 70 |
| | 02/2017 - 03/2017 | 38 | 2 | 27 |
| | 09/2017 - 10/2017 | 43 | 2 | 36 |
| All ties | 2016 | 1 | 306 | |
| | 2017 | 1 | 369 | |

visible in the graph, namely individuals who have no strong ties. Since there is a great difference between the amount of nodes in the strong tie network and in the network of all ties, there has to be a substantial set of individual that have only weak ties. This indicates that these individuals have not settled into a team during the measurement period or don't work consistently in one team in the first place. Based on the network size measurements in Table 4.1 approximately one third of the network are such individuals who have only ties of weak or intermediate strength. Thus, independent teams are the predominant way of working in the organisation but evidently not the only one.

Because of related privacy issue, the names of the members in the components won't be included in this study. However, by comparing between snapshots how individuals are positioned it is possible to investigate how they move from one component to another. Thus, the data suggests that even, if some information may not transfer from one team to another constantly, individuals do transfer and this leads to the distribution of information and knowledge. Naturally this leads to substantially larger latency and therefore may hinder the development of the organisation. Furthermore, in the case of distributing information mainly with organisation members the velocity of distribution is to a large extent dependent on the frequency of changes in the organisation structures. In practice, if most of the

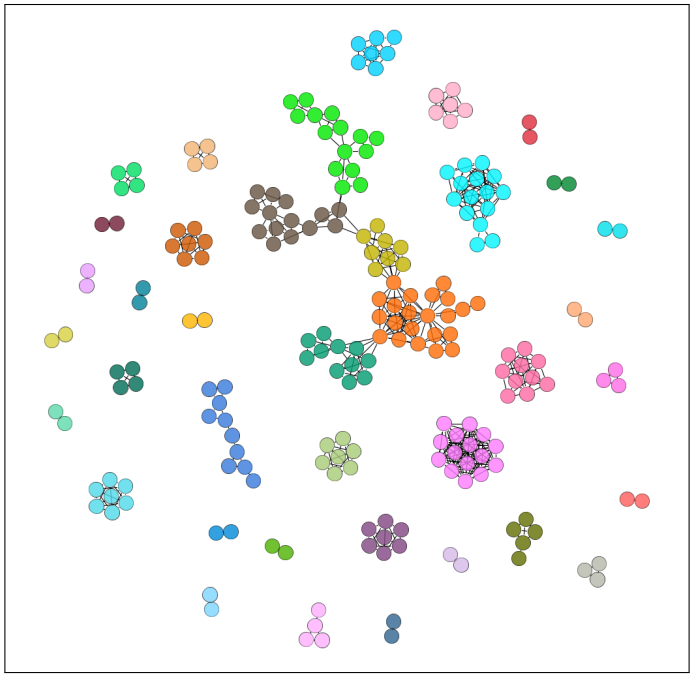


**Figure 5.6.** Disconnected components in the network of strong ties in 09/2016 - 10/2016. Colours indicate community structure. One of the components is significantly larger than the others (70 individuals) and consists of multiple communities.

independent teams in the organisation are long-lived and subject to little change, some teams may get useful knowledge only several months after it has first been discovered inside the organisation.

## 5.6 Network node degree

To provide one more metric to compare the network in this study with typical social networks, network node degrees and especially their distribution is considered. Table 5.6 presents the distributions with both average network node degree and maximum network node degree. As with the other variables that are investigated in this study, also node degree is substantially different in the strong tie networks compared with the networks with all ties. In the case of node degree, this is self evident because the restriction to tie strength directly leaves the number of ties out. In fact, that can be used to estimate the amount of weak ties individuals have: while, on average, members of the organisation have approximately five strong ties, they have ten weak ties. This is only an imprecise estimate, though, since some members in the network of all ties have purely weak ties and are not included in the strong tie network.

A surprising feature of the degrees is that the maximum degree is relatively close to the average degree. The maximum is only two to three times larger than the average in the strong tie networks and four times larger in the rest. Social networks are known to be scale-free networks where the most connected individuals have extremely large degrees compared to the average network member (Watts, 2004). Thus, when it comes to the node degree, the studied network has untypically narrow range of degrees.

To further study the distribution of node degree, it can be considered if the form of the distribution is typical for social networks. As Miritello et al. (2013) describe, the distribution should follow long tailed power law. In Figure 5.7 the cumulative probability of node degree is plotted to a double logarithmic scale. In case of power law distribution, the plot should follow straight line in the log-log scale (Clauset et al., 2009). In the related figure (Fig. 5.7), it is clearly visible that the distribution of

**Table 5.6.** Average and maximum degree of nodes in the network

| Ties included | Time period | Average degree | Maximum degree |
|---|---|---|---|
| Strong ties | 09/2015 - 10/2015 | 5.1 | 11 |
| | 02/2016 - 03/2016 | 4.6 | 12 |
| | 09/2016 - 10/2016 | 5.1 | 20 |
| | 02/2017 - 03/2017 | 5.5 | 17 |
| | 09/2017 - 10/2017 | 6.7 | 17 |
| All ties | 2016 | 15 | 62 |
| | 2017 | 16 | 67 |

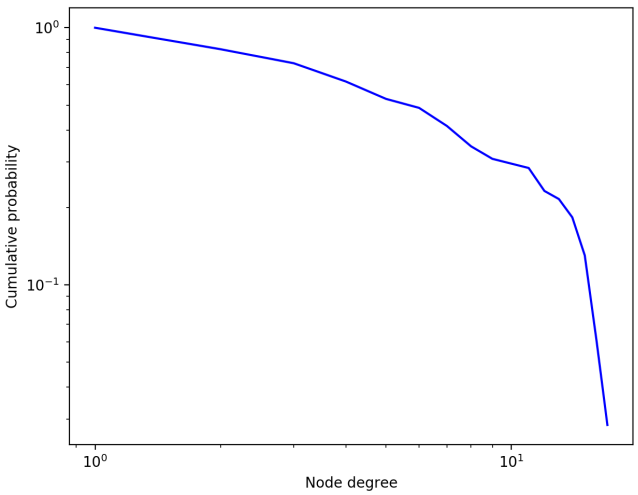
node degree does not follow power law in the studied network since the distribution doesn't fit into straight line at any point. This result is an indication that the network may be missing some features of a typical social network.

One potential explanation for the lack of fit to power law in node degree distribution is the dataset used for the analysis. As discussed earlier, it is likely that the data doesn't include all weak ties in the organisation. If it is expected that the highest degree nodes form due to a large number of weak ties, the nature of those nodes would not be visible in the data. However, this bias in the dataset may not fully cause the untypical distribution. Thus, the organisation may have abnormally equal members as far as degree centrality is considered.

## 5.7 Effects of cut-point selection to outcome variables

As can be seen in Figure 5.8 selecting cut-point parameters in work time reporting data processing substantially affects the variables of the resulting network. For instance, increasing the length of the measured time period from two to twelve months increases the amount of nodes in the network by 32% (from 262 to 346). Also, that same change in the parameter value increases the density of the network by 45% (from 0.031 to 0.046). To compare these results with findings about perceived tie strength, Murray et al. (1981, p. 125) show that there is only a small difference between four contacts in a year compared to four contacts during two months: changing the frequency doesn't significantly change the amount of individuals in their results who perceive the tie as strong (24% vs 21%) or intermediate (36% vs

**(a)** Degree distribution in 09/2017 - 10/2017 (only strong ties)




**(b)** Degree distribution in 2017

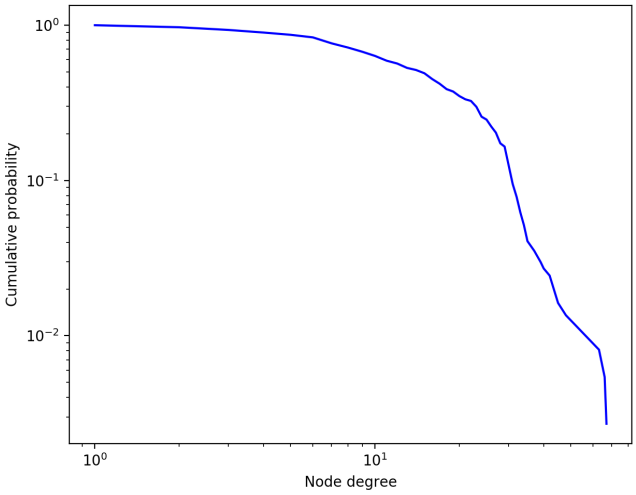
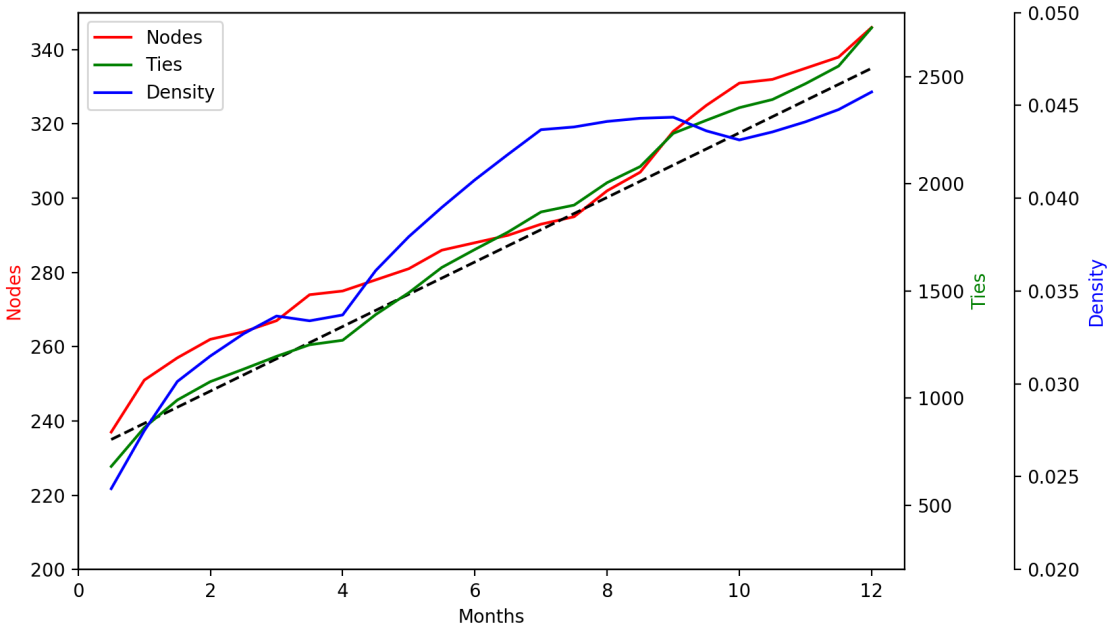



**Figure 5.7.** Network node degree distributions plotted to a log-log scale. The plots represent the complementary cumulative probability of node degree. From the plots it can be discovered that the distribution doesn't fit power law but first the cumulative probability decreases too slowly and finally there are clear cut-off points.

**(a)** Network variables as a function of period length




**(b)** Network variables as a function of day threshold

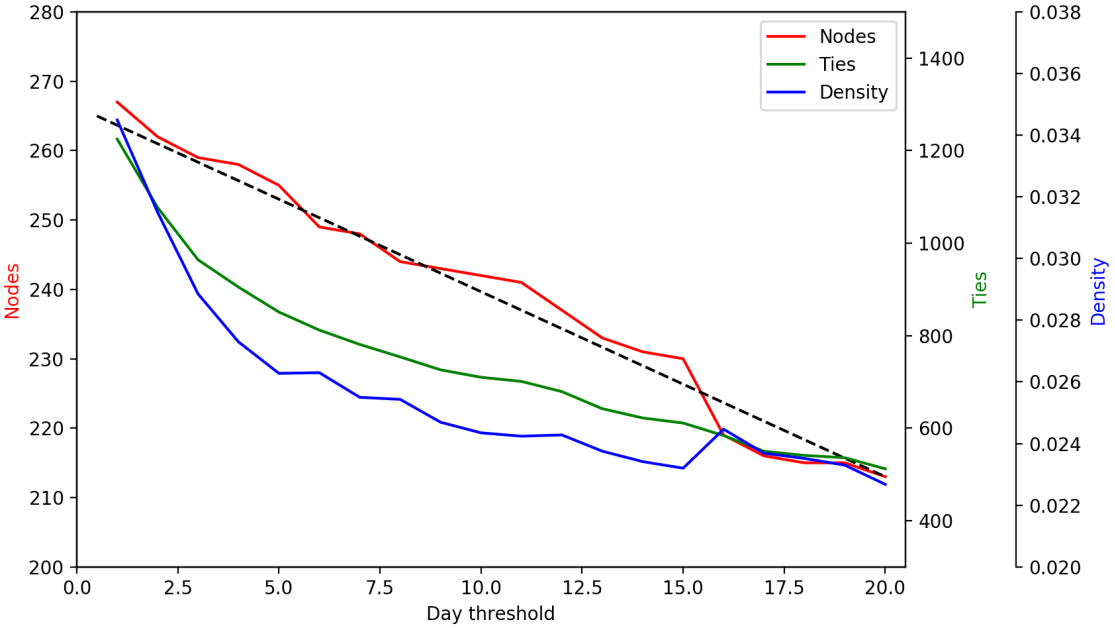



**Figure 5.8.** Effect of cut-point parameter selection to network variables (the amount of nodes and ties, and network density). The upper graph varies the amount of months included in the measured time period starting at 09/2016. The day threshold for that graph is four days. The lower graph varies the amount of days worked together that is required for a tie to be accepted. Time period in the lower graph is two months: 09/2016 - 10/2016. Both graphs have dashed straight line to aid in comparison to a linear relationship.

36%). For weak ties the sample size is too small for proper comparison. Similarly, when the amount of days spent together in two months is increased from two to five, the amount of ties in the network decreases by 26%. In the results of Murray et al. both these frequencies fall inside the same category which supports the suggestion that these frequencies can be considered about similar.

When the first graph in Figure 5.8 is considered no major non-linearities can be observed in the amount of nodes or ties. However, the development of network density has certain irregularities. Especially near the four and ten month points the increase halts or changes to decrease. With further analysis, those points can be identified as the winter and summer vacation seasons. This is an important finding: when selecting any period shorter than a full year there is a possibility that inclusion (exclusion) of major vacation seasons biases the data towards lower (higher) density. Furthermore, when extending the measured period from 5.5 to 6 months the seemingly small change may introduce a minor decrease in density and a major irregularity to the growth of density. Thus, the measured period should be a full year or approximately under five months to reduce the probability of selecting a poorly representative set of data.

The second graph varies the amount of days that is required for two organisation members to work together for the tie to be accepted. There are two noticeable features in the graph that can complicate using work time reporting data. The first feature is the rapid decrease in density that is already discussed above. To illustrate the issue, the selection between two or five days has more impact on density than the selection between five and twenty days while previous research (Murray et al., 1981; Reagans & McEvily, 2003) considers the latter to have clearly larger impact on tie strength. The second feature is the decrease in amount of nodes and increase in density in the network when the threshold increases from 15 and 16. This finding indicates that when selecting the parameter value for the day threshold, only a change of one day may accidentally lead to a surprisingly dense and small network. If there are more similar irregularities when a different time period is selected, studying strong ties in the network may produce findings that represent poorly the same network with intermediate and weak ties involved.

# 6. Discussion

## 6.1 Summary

In this section, the research questions are visited again with the purpose of summarising answers to them. To provide extensive answers both previous research and empirical findings are combined together. In addition to concerning research questions the section discusses limitations, practical implications, and required future research that arise from this study.

*Does social network fragmentation cause hindrances in performance for team based organisations?*

Based on both previous literature and empirical findings from this study it is clear that providing one simple answer to this research question is not possible. There are multiple perspectives that have to be taken into account and making clear-cut conclusions about complex data is fundamentally difficult. Nevertheless, it is likely that the answer provides new and useful information.

When the studied network is compared with typical social networks, there is a clear difference in degree centrality distribution. While typically social networks are so called small-world networks (Watts, 2004) this feature seems to be partially lacking from the network at hand. According to Miritello et al. (2013), small-world networks have scale-free degree distribution where the frequencies of nodes with certain degrees fit power law. Frequencies in the studied network don't fit power law

but there are too few well-connected individuals. This indicates lack of small-world features and thus lack of access over the network. The significance of this issue is increased due to the tendency of network outcomes to change rapidly when relative amount of local ties increases compared to global ties (Watts & Strogatz, 1998).

A similar tendency related to lack of small-world features is present in the frequency of large communities. As Guimera et al. (2003) has shown, community sizes should also follow power law. The measured community sizes lack this feature partially. There is a reason to expect that this is another indication of hindrances that arise from the structure of the organisation.

Out of the potential issues present in the network, one is high network constraint. As the analysis of the network indicates the organisation consist mostly of teams that are cliqued to a large extent, having high constraint is expected (Rosenthal, 1997). Even if there wasn't fragmentation in the organisation the high constraint and restricted access to new people and information is potentially one of the greatest hindrances the team structure causes. To delve deeper into the analysis, Figure 5.2 shows how the communities in the organisation are substantially denser than the organisation in general. If, in addition to the mean density, the standard deviation is considered it can be inferred that a certain part of the communities have to have density very close to 100%. Thus, the analysis truly supports the notion that the organisation consist at least partially of cliques. Furthermore, purely the internal density of teams is shown to decrease network range (Reagans et al., 2004). From this basis, there is a high likelihood that the performance of organisation is hindered to some extent by constraint.

Even if the organisation has cliques and its communities are highly internally integrated this does not constrain all of its members. The empirical evidence indicates that while some individuals are constrained there is part of the members of the organisation is not. Figure 5.5 illustrates the situation: constraint is distributed from highly constrained to loosely constrained. As network range is the complement of constraint (Reagans et al., 2004), the individuals with low constraint, i.e. high range, benefit the organisation. This is since range improves the distribution of more diverse knowledge (Reagans & McEvily, 2003). Furthermore, research by Burt

(2004) indicates that individuals with lower constraint tend to produce better ideas for their surrounding organisation.

When it comes to the results related to constraint that the social network analysis reveals, there is an even better indication than only the individuals with low constraint: Table 5.4 shows how the constraint on average in the organisation has decreased over time. In other terms, the distribution of diverse knowledge and development of new ideas can be expected to increase also in the future.

Finally, the most significant observation that constraint measures lend themselves to is the wide distribution of constraint. That is a concrete proof about the diversity of the structure of the organisation: it is not purely formed by tightly connected separated teams but there is a substantial number of individuals who are well connected with high network range. Thus, this study suggests that expecting a team based organisation to have only teams is too simplistic of a view.

Both Martin and Yeung (2006) and Burt (2000) offer interesting findings about ties in an embedded context: ties are more likely to exist and persist between individuals A and B if there is individual C with ties to both A and B. This increases the importance of the members of the organisation that the analysis shows to be located "in the middle". However, the Figure 5.5 indicates that there is only limited amount of individuals who have ties spanning over the entire organisation. Thus, it can be expected that those few connecting organisation members do not tremendously increase the likelihood of two individuals on the opposite sides of the network to be connected. However, with further analysis of the constraint histograms, there is also a substantial amount of individuals with intermediate range. I suggest that these ties help in reducing the fragmentation of the organisation and conclude that the lost potential in lack of cross-organisational ties is a fraction smaller than it would be without the individuals who have ties all over the network.

While network constraint is a useful measure also considering specific elements of the network aid in assessing how well information flows in an organisation. One of such elements are weak ties. For instance Granovetter (1973) regards them as highly important in, e.g., the spread of new ideas. Also, while all ties allow knowledge to be distributed around an organisation, according to White and Houseman (2002),

weak ties support the distribution of the most useful knowledge. The results from the analysed organisation provide compelling evidence that there indeed is wealth of weak ties: see difference in degree between the network of all ties and the network with only strong ties in Table 5.6. Furthermore, the location of weak ties is similar to typical social networks: strong ties form the core of communities and weak ties connect those communities together and bridge structural holes. This is the pattern that Granovetter originally expected varying strength ties to form. Particularly, a sign that indicates a healthy tie structure in the organisation is that there are often multiple individuals who have weak ties to outside organisation. In conclusion, even if there are highly constrained parts in the network, the hindrances to the organisation are quite confined. In other terms, social network analysis doesn't reveal substantial losses of potential in the team based organisation.

After Granovetter (1973) highlighted the importance of weak ties there has been research to show what the role of strong ties is in social networks. It has turned out that in certain contexts strong ties are more important than weak ties: When communicating complex knowledge weak ties may not fill the necessary requirements (Reagans & McEvily, 2003). Also, strong ties reduce conflicts in organisations (Nelson, 1989). When the results from the analysed social network are considered, it becomes apparent that there is lack of strong ties between communities. In more detail, most of the communities are cliques with no or few strong ties to other communities. While this finding indicates loss of potential in the organisation it is not necessarily surprising. It is presumable that the few ties between cliques are weak and not strong (Granovetter, 1973).

As weak ties can be shown to connect cliques to the larger network a question arises about if those ties are held by the correct organisation members. While weak ties are important by themselves it is also beneficial if key members in cliques are the ones connected well (Provan & Sebastian, 1998). The difficulty related to the organisation studied is that it is not possible or at least not easy to determine who are the key members in the cliques that should be connected. That is related to the lack of hierarchy: there is no direct source of information for finding team leaders or other managers. This is, first of all, a challenge for research, but also a potential

challenge for the organisation. The issue for the cliques may be that they are not able to find the member who should ensure the clique has connections to other cliques.

So far, it has been concluded that there are findings supporting the fact that there are hindrances but also findings indicating those hindrances being only limited. However, they are based mostly on the structure of the social network. The findings of Reagans and Zuckerman (2001) show that the importance of social network structures depends on the internal features of the team. Namely, if the team possesses a wide variety of skills and a large knowledge base it is less dependent on connections to outside organisation. Thus, a team that has only a few weak ties may be able to function as well as team with more weak ties – if the team with less network range has all the necessary knowledge internally that is required for it to achieve its target. The restriction imposed by the dataset used for this study is that analysing the internal skill set of a team is not possible. However, it can be concluded that the cliques in the organisation with low range suffer from the team structure the more they require skills the team itself doesn't have.

If the discussion is continued about skills, it has been found that network structure affects individuals' skills – namely the skills of communication. When members of a social network are less embedded in a clique and have more diverse pool of contacts they also possess better communication skills (Reagans & McEvily, 2003). This phenomenon is likely to increase the disparity between parts of the studied organisations: while some individuals have a high network range and have a tendency to be better at communication, others in the network are more constrained and have more restricted communication skills. The empirical findings this conclusion stems from is that individuals in the studied organisations have substantial differences in how constrained and connected they are (see histogram of constraint in Figure 5.5 and graph of node degrees in Figure 5.7).

An aspect that is not visible in the analysed data but that should be taken into account is the amount of connections outside projects. There is not a sufficient basis for estimating that metric but the available data enables a very restricted form of inference: it can be shown that the ties individuals have from their current or previous projects don't necessarily restrict the amount of ties outside projects. This is

because members in social networks are shown to invest more time in collaboration up until 40 contacts (Miritello et al., 2013). The results show that individuals in the organisation form only approximately 15 ties during one year with their colleagues in projects. From this finding, it can be concluded that the social network analysis thus far has provided a little too pessimistic picture about the situation. However, it is difficult to approximate the size of that error – especially it should not be overestimated since the network already has a large amount of weak ties that appear in the data.

Finally, there is both theoretical and empirical evidence related to the persistence of ties in the network that affect the end result. About tie persistence, it has been shown that long history together increases the persistence of a tie; but increased distance between the individuals in the dyad reduces the likelihood that the tie persists over time (Dahlander & McFarland, 2013; Martin & Yeung, 2006). When the empirical findings from the analysed organisation are considered, members of communities can be shown to have spent over a year together. However, simultaneously, individuals seem to occasionally move from community to another substantially increasing the distance between her old contacts. Only using the available work time reporting data it is not possible to fully estimate the distance but since some communities are clearly rather independent and separated the distance may be too high for the old tie to be maintained. Based on these results, it is difficult to estimate if the persistence of old ties is a hindrance to the team based organisation.

As it has turned out, the individuals with high range and their bridging ties are an important feature in the social network reducing the effects of fragmentation. However, when tie persistence is considered, those bridges are the ties that are the most prone to decay (Burt, 2002). Furthermore, the environment around those bridges affects if they are maintained or not (McPherson et al., 2001). For instance, if individuals maintaining the bridge experience a major change in their context, e.g., change from one team and location to another, the bridge may decay. When the organisation at hand is analysed it seems like such transitions are not unlikely: during one-year periods it can be seen that organisation members move between communities. This suggests that a team based organisation is relatively prone to

becoming fragmented since its bridges holding the network together are fragile by their nature.

A network phenomenon that is not discussed in the empirical part of this study but is present in previous literature is the reconnection of old ties. Levin et al. (2011) has shown that reconnecting old ties can be a surprisingly effective method of for instance getting advice. Analysis of the studied network shows that individuals in the organisation may have an immense pool of contacts that they are connected to with a dormant tie. If those tie can be reconnected reaching people around the organisation is not issue at all. This is a potential aspect reducing the challenges team based organisations encounter but in this study its effect can't be verified.

The conclusions above show that there are fragmentation related phenomena in social networks in team based organisations that hinder the performance of the organisation and cause it to lose some of its potential. However, the studied social network shows that a team based organisation my not be completely formed out of cliques and can have surprisingly good abilities for maintaining its performance.

*From social network perspective, are highly independent teams a beneficial organisation structure?*

When the social network of the studied organisation is analysed it can be observed that the density inside the communities in the network is very high. Especially if the organisation is reduced to only strong ties the remaining communities are nearly completely cliqued. At least in short term this internal density in teams improves the performance of those teams (Reagans & McEvily, 2003). Furthermore, Ancona and Caldwell (1992) suggests that while the range in the network might be restricted the internal density in teams benefits the organisation more.

Also, more generally literature shows that cliqueness of teams improves their performance (Reagans et al., 2004; Reagans & Zuckerman, 2001). However, all studies researching the subject haven't found there to be a causal relationship (Sparrowe et al., 2001). Thus, a conclusion can be made that at least in short projects the independent teams in the studied organisation have advantage in performance but it is not definite whether the situation remains that way when the length of the project increases.

The results from the social network analysis show that a great proportion of the ties in the network is Simmelian ties. Those ties improve the collaboration in the team for instance by reducing bargaining power any single individual has and improving the ability of the team to resolve conflicts (Krackhardt, 1999). This is an advantage that the organisation could not achieve without its team being as internally dense as they are.

One feature that the organisation has not been able to fully reach with independent teams is equality among members of the whole network – quite the opposite, actually. If the degree centrality of individuals is considered a more central position is shown to be connected with higher status (Lincoln & Miller, 1979). In the studied organisation, the social network has noticeable signs of uneven distribution of degree: some individuals are better connected than others. However, it should be noted that the situation is likely to be better than in organisation typically. This is because, as Figure 5.7 shows, the network is lacking in nodes with extremely high degree centrality.

Nevertheless, there are other features indicating inequality in addition to uneven degree centrality distribution. One of such features is the concentration of network range for a limited group of individuals. Burt (2009) describes how network members with more range, or less constraint, have a superior position compared to other members when it comes to for instance the perceived value of ideas. As described under the first research question the organisation clearly has individuals who have better range than others. Naturally, the organisation as a whole benefits from the position of these individuals. However, this may lead to a situation where the success of the organisation is attributed unevenly emphasising those well-connected individuals.

While ties integrating the whole social network of an organisation and its communities are emphasised they are not the only structure that benefits collaboration in a network. There would be additional benefits available if certain communities in the organisation had overlap. This is especially important when there are multiple communities that are required for reaching a common target. (Provan & Sebastian, 1998) The results have some indications that there is overlap between communities

but at the same time the cliques in the network of strong ties are mostly completely separated.

These insights show that, from social network perspective, the team based organisation gains advantage from its structure. However, the benefits may be short-lived in some situations. Furthermore, there are issues like inequality that still remain despite the organisational structure.

*Can social network analysis reveal issues and strength in a highly team based organisation?*

Both research questions above prove that social network analysis can be a useful tool for revealing issues and strengths in highly team based organisation. Most significantly the analysis has illustrated the state of the social network in the organisation and both confirmed risks and benefits. Furthermore, at the simplest level the analysis has shown the extent of difference between individuals and their positions: certain individuals benefit more from the structure and the rest benefit less. If the organisation strives for equality among its members, analysing its social network will certainly help.

When it comes to more specific pieces of knowledge, the social network analysis enables the organisation to monitor both its fragmentation and the constraint of individuals in its network. Additionally, constraint measures are comparable with other organisations to a certain extent and they help the organisation to evaluate its success in fostering the distribution of useful information and ideas.

Despite the promising results, social network analysis seems to have its drawbacks: the results of this study vary substantially and there are both benefits and hindrances related to almost every subject. This reduces the ability of the analysis to provide clear actionable insight. Thus, social network analysis can reveal issues and strengths but it may not be as helpful in solving and solidifying them.

One restriction that reduces the benefits of social network analysis is the lack of visibility in dormant ties. Levin et al. (2011) presents that they have an important role in utilising the potential of one's social network. Still both the method used in this study and the methods typically used in social network data gathering don't allow assessing the reconnectability of ties.

*Can work time reporting data be used effectively in social network analysis?*
Compared to more traditional methods, i.e., surveys (in e.g. Reagans et al., 2004), work time reporting data has shown its ability to provide information about tremendously larger organisations. The network handled in this study has up to 400 nodes and there have been no concrete issues in handling the information about their ties – including more detailed data related to communication patterns. In this sense, work time reporting data performs as well as for instance email data used by Guimera et al. (2003).

Furthermore, since the amount of effort required to gather more data does not grow linearly work time reporting enables adding more dimensions to the analysis. This study shows how added time dimension broadens the analysis even if it did not substantially affect the absolute investment put in to the gathering of the data. Thus, research based on work time reporting can provide new knowledge about network features that could not be studied otherwise and can reduce the risk related to variation more effortlessly than research based on traditional data gathering methods.

A dimension that lacks from the data used in this study is the content and the nature of ties. Especially level of personality is important information when the strength of a tie is considered (Granovetter, 1974). Nevertheless, it has been shown in this study that strength of a tie can be inferred using other methods if necessary.

As the central part in using work time reporting data is the inference of the social network using the data, considering the feasibility of that endeavour is a matter of great significance. The results of this study show that there are certain irregularities and pitfalls that have to be considered in the process but there is no indication that it would not be feasible. Instead the analysis done in this study is a proof that work time reporting is a good basis for social network analysis.

A significant restriction related to work time reporting data as a basis for social network analysis is that it does not provide clear indication about the existence of ties that are not directly related to work done under a project. This restriction is, however, less severe on organisations where this reporting and its validity is financially crucial.

Finally, the conclusion is that work time reporting data can be used effectively in social network analysis and in certain situations it is even better data source than what have been used traditionally. However, at the same time work time reporting substantially restricts the analysis of ties and network structures that are not related to work itself. Thus, the context where the analysis is done should be carefully considered.

## 6.2 Limitations

The most significant limitation in this study is that in the used work time reporting data, it is not possible to show for certain if individuals have truly worked together. It is possible that in some cases some project is done in multiple locations or members in same project have done work only from home or in other ways from remote locations. In such situations the analysis indicates a tie between those individuals who in reality does not exist. However, the practises in the organisation should minimise this as teams strive to always work together and avoid working outside customer premises or company own office.

Furthermore, the work time reporting does not contain any traces about ties that are formed outside work assignments. This limitation indicates that the fragmentation of the organisation is likely to be less severe than the data indicates. It is important to note that the error caused by this issue is possible only towards too few ties. To assess the effects of this problematic aspect, it does certainly affect the results but there are also factors restricting problems. Namely, the teams in the organisation are located in different locations which reduces the likelihood that any two individuals form a tie without working in a same project.

When it comes to the analysis and the handling of time dimension in the results, the chosen method is effective but not optimal. As Duan et al. (2012) describes, there are better solutions than snapshots in handling dynamic networks. However, since the dynamics of the network are not the key aspect in the analysis, the lack of more sophisticated method in this part is not detrimental for the reliability of the results.

Since the work time reporting data lacks the information about the content of

communication in contacts, one can't be certain about the content of discussion inside bridging ties. More precisely, it may be that bridging ties do not transport information that is useful for the cliques being bridged. Nevertheless, previous research has shown that bridging ties do improve transfer of, e.g., more useful ideas and there is no reason to expect that those findings would not apply to this network also.

Finally, one issue present in the research that this study relies on is difficulty to show robust causal relationships between networks structure and knowledge transfer. As Reagans and McEvily (2003) describe in their paper it is possible that network structure is not the driving force affecting knowledge transfer but unobservable features in individuals improves both. They explain that those individuals simply have "greater absorptive capacity".

## 6.3 Practical implications

The cliqueness and constraint observed in part of the communities proofs how independent teams really can be. With low range, reaching for advice is truly cumbersome in those communities. To mitigate this issue teams in the organisation should be built to be able to succeed as independent. As Reagans and Zuckerman (2001) suggest, cliques require less external connectivity and range if they have all necessary skills embedded in the clique.

The results of this study show that independent teams are beneficial for organisations and should not be avoided. If the above mentioned skill set in the team is ensured to be wide enough the social integration inside the team helps it to function well and may increase its performance. Furthermore, complex ideas are distributed between team members with strong ties to each other which accelerates knowledge sharing in the organisation.

Both theoretical and empirical evidence suggest that social network analysis can be successfully used to analyse strengths and weaknesses in organisations. When the findings especially with regard to network constraint and inequality are considered, a recommendation can be formed for companies to use social network analysis to

understand their organisation. This is valuable for all organisations independent of whether there is a official organisation chart or not: every organisation has both formal and informal structures and the informal network affects the functioning of the organisation substantially (Lincoln & Miller, 1979).

Finally, organisations should consider the positions of individuals in its social network: individuals with low range should be offered the ability to better connect with colleagues in the organisation to reduce risks related to inequality. The potential issues can be anticipated both by analysing directly the social network of the organisation or by using proxy variables like length of stay in previous project.

## 6.4 Future research

Since work time reporting data has shown its strengths in social network analysis, further evaluating its accuracy should be considered as an important target for future research. The effort should concentrate around two questions: how the ties formed during projects do persist and how great proportion of ties is formed outside collaboration in teams. By answering those questions, accuracy of analysis done based on work time reporting data can be further estimated and the accuracy can be increased by taking into account the persistence of ties and ties that are not explained in the reporting data. The study could be implemented by surveying the members of the organisation. The first topic should be, which old teammates they have been in contact after the project has ended. Also, the survey should prompt the members about who they have been in contact with outside any project or assignment.

Another subject for future research is the concrete adoption of new ideas in teams in relation to the constraint the team experiences. Since this study has been only able to show that there are differences in constraints, research should also strive to observe whether those differences lead to restricted access to new information in team based organisations. This research is required because there is a lack of evidence for the benefits that are offered by individuals who work with a large group of teams simultaneously. Based on the results of this study, the members of the

organisation that work in multiple projects have to divide their attention which may reduce the benefits any single team receives.

While it is avoidable that social network analysis is difficult and burdensome for an organisation, there should be also available effective proxy variables enabling assessing the state of the organisation with less effort. The results from this study indicate that length of stay in a single project and the amount of concurrent projects may be related to the network constraint an individual experiences. Research improving understanding about that relationship would be especially important for team and project based organisations.

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# Appendices

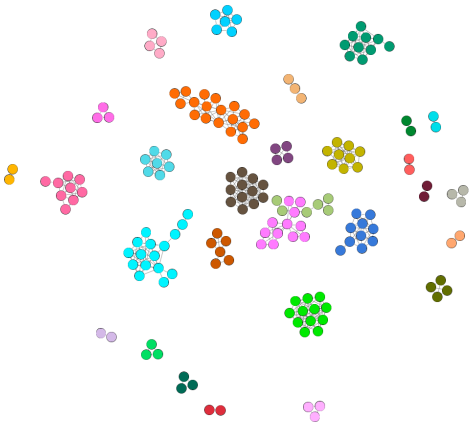
# A. Constraint algorithm

Implementation of algorithm in JavaScript:

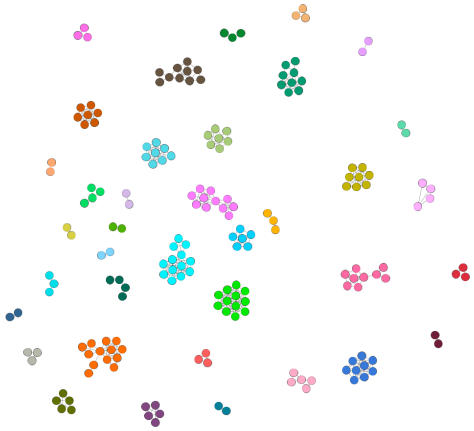
```
const R = require('ramda')
const math = require('mathjs')

if(!process.argv[2]) {
  console.error('Failed, give communications file: node constraint.js communications.json')
  process.exit()
}

const communications = require(`./${process.argv[2]}`)

const allConstraints = R.mapObjIndexed((communications_a, name) => {
  const contacts = R.keys(communications_a)

  const r_contacts = contacts.map(b => {
    const S_ab = communications_a[b]

    const S_others = contacts
      .filter(c => c != b)
      .map(c => {
        const S_ac = communications_a[c]
        const S_cb = communications[c][b] || 0
        const prod = S_ac * S_cb
        return prod
      })
    const sum_S_others = R.sum(S_others)
    return Math.pow(S_ab + sum_S_others, 2)
  })

  const R_a = R.sum(r_contacts)
  return R_a
})(communications)

const constraints = R.pipe(
  R.toPairs,
  R.filter(([_, constraint]) => constraint > 0),
  R.fromPairs
)(allConstraints)

const values = R.values(constraints)
const mean = R.sum(values)/values.length
const std = math.std(values, 'uncorrected')
const median = math.median(values)

console.log(`${math.round(mean, 2)} & ${math.round(std, 2)} & ${math.round(median, 2)}`)
```

# B. Graphs

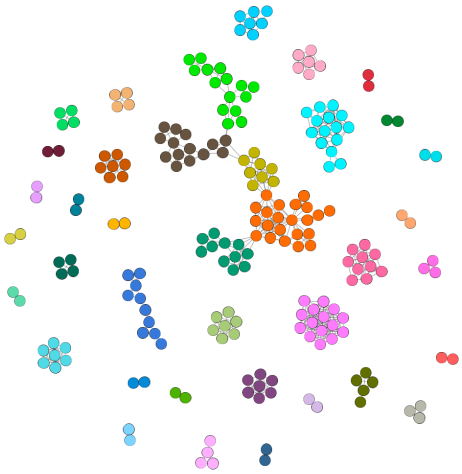
Company social network as used in analysis. Colours indicate communities.



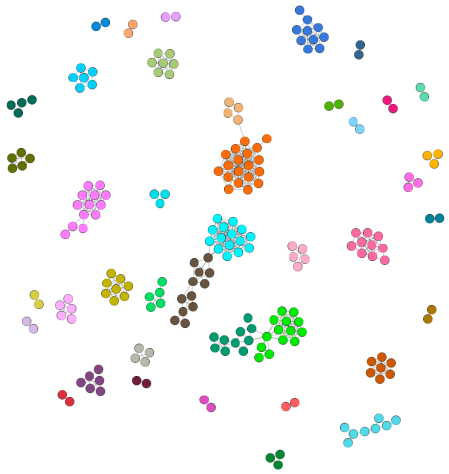
**(a)** Network of only strong ties for 09/2015 - 10/2015



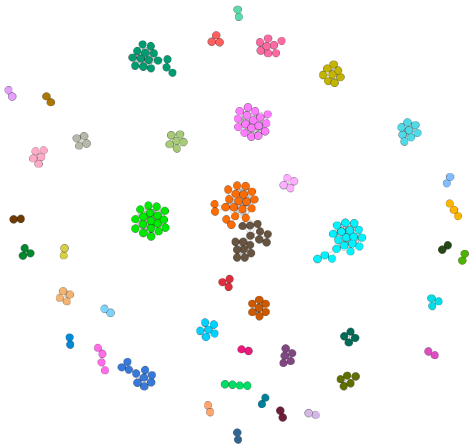
**(b)** Network of only strong ties for 02/2016 - 03/2016



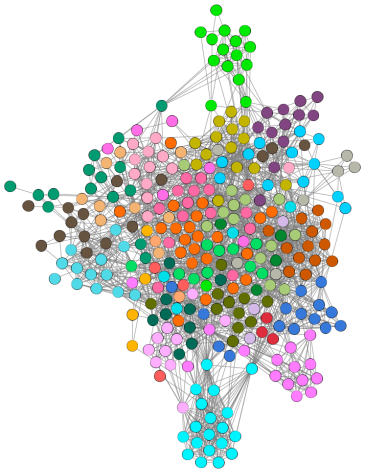
**(c)** Network of only strong ties for 09/2016 - 10/2016



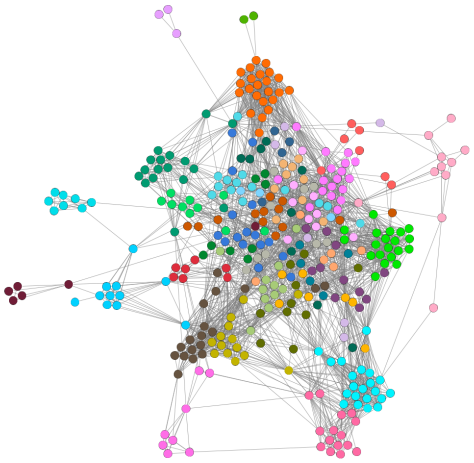
**(d)** Network of only strong ties for 02/2017 - 03/2017



**(e)** Network of only strong ties for 09/2017 - 10/2017



**(f)** Network of all ties for 2016



**(g)** Network of all ties for 2017